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SURVEY OF PACKAGING REQUIREMENTS FOR RADIATION PASTEURIZED FOODS

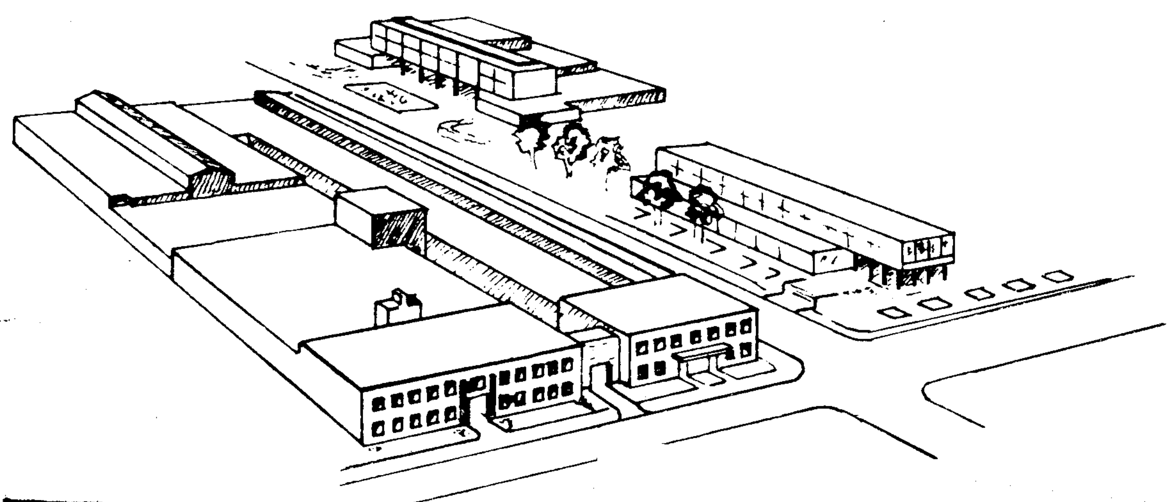
BY

CENTRAL RESEARCH AND ENGINEERING DIVISION

AND MEMBERS OF THE TECHNICAL CENTER

CONTINENTAL CAN COMPANY

CHICAGO ILLINOIS



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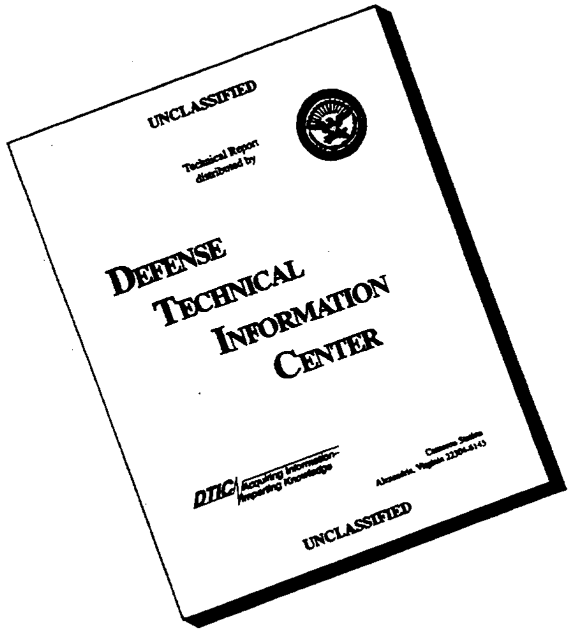

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Central Research and Engineering Division

and

Members of the Technical Center

CONTINENTAL CAN COMPANY, INC.

CHICAGO, ILLINOIS

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SURVEY OF PACKAGING REQUIREMENTS
FOR RADIATION PASTEURIZED FOODS

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Abstract

The literature pertinent to the use of packaging materials for radiation processed foods has been reviewed and tabulated. The conclusions drawn from these data have been applied to the probable package engineering requirements of five fishery and five fruit products under investigation by the AEC for shelf life extension by radiation-pasteurization. The needed research and field testing program is outlined.

A bibliography of approximately 450 references and 18 tables of data are included.

Introduction

The present study was undertaken by Continental Can Company to assist the Division of Isotopes Development, United States Atomic Energy Commission, in establishing a research and development program based upon previous work conducted on the effects of radiation, storage, and temperature on packaging materials and on packaging materials in contact with air, food, and food constituents. The intent of this study is to organize such information for those persons interested in selecting packaging materials for radiopasteurized foods.

Present information on the effects of radiation on packaging materials at doses ranging from less than 1 megarad to 6 megarad indicates that most food packaging materials will perform in a "generally satisfactory" manner in conjunction with radiation pasteurized foods. Thus if a packaging material or combination of materials is satisfactory, particularly for an unirradiated food, it will probably be "generally satisfactory" for the same irradiated food.

Although most materials may perform in a "generally satisfactory" manner in packaging radiation pasteurized foods, optimization of packaging materials and package design for this application will be an evolving rather that a static technology. For this reason, the major emphasis of this study has been placed upon the properties of packaging materials which would be used under conditions appropriate to the food items of direct interest in the field of radiation preservation of foods. Only a limited amount of attention will be directed in this report to specific designs of packages. It is our

opinion that the principal problem areas are more related to optimization of packaging materials for this application and that if an adequate documentation of research work is performed, the package designer will have data available from which to make the materials selection appropriate to the specific food commodity, the radiation source geometric configurations, and the food distribution system.

Part I of our study provides a tabulation of experimental information on the behavior of specific packaging materials subjected to various environments used in food irradiation. These data provide the basis for a realistic and practical appraisal of the need for future experimental work on packaging materials.

Part II discusses the relationship of the radiation pasteurization process, package design parameters, and selected marketing factors to the ten specific food items under immediate consideration.

Part III of this study delineates the additional needs of the AEC program from the packaging supplier's viewpoint with the objective of bringing a marketable food item in a suitable package to the consuming public in the shortest possible time.

Appendix

A topical bibliography, a bibliography arranged by author, and a glossary of terms are provided.

Summary

This report is a compilation of a literature review and interviews with specialists in the field on the behavior of packaging materials in food irradiation environments. It indicates that only minor changes in mechanical and chemical properties occur at thè radiation pasteurization dosage level (less than 1 megarad).

Presently known engineering techniques can probably be employed with a reasonable degree of assurance that an adequate package can be provided for the ten selected food items.

A guide to the applicability of food package types for the selected fishery products (Table 12) and fruit products(Table17 and 17 a.) are provided in Part II.

The following information was not available:

1. The exact package designs for the selected food items.
2. Experimental evaluation of the potential migration of irradiated packaging materials into foods.
3. The possibility of the packaging materials rendering the food organoleptically unacceptable.
4. The extent to which refrigeration will tend to minimize the objectionable aspects of items 2 and 3 above.

Recommendations for acquiring the additional information necessary for optimization of packages for radiation-pasteurized foods include a packaging material research program and a cooperative information program to include food package manufacturers.

Statement of the Study Objective

The object of this study is to assist the AEC in bringing radiation-pasteurization of ten selected foods to the point of commercial feasibility. These foods are five fishery and five fruit products as follows:

Fish: Haddock fillets, shucked clams, flounder fillets, cooked crab and cooked shrimp.

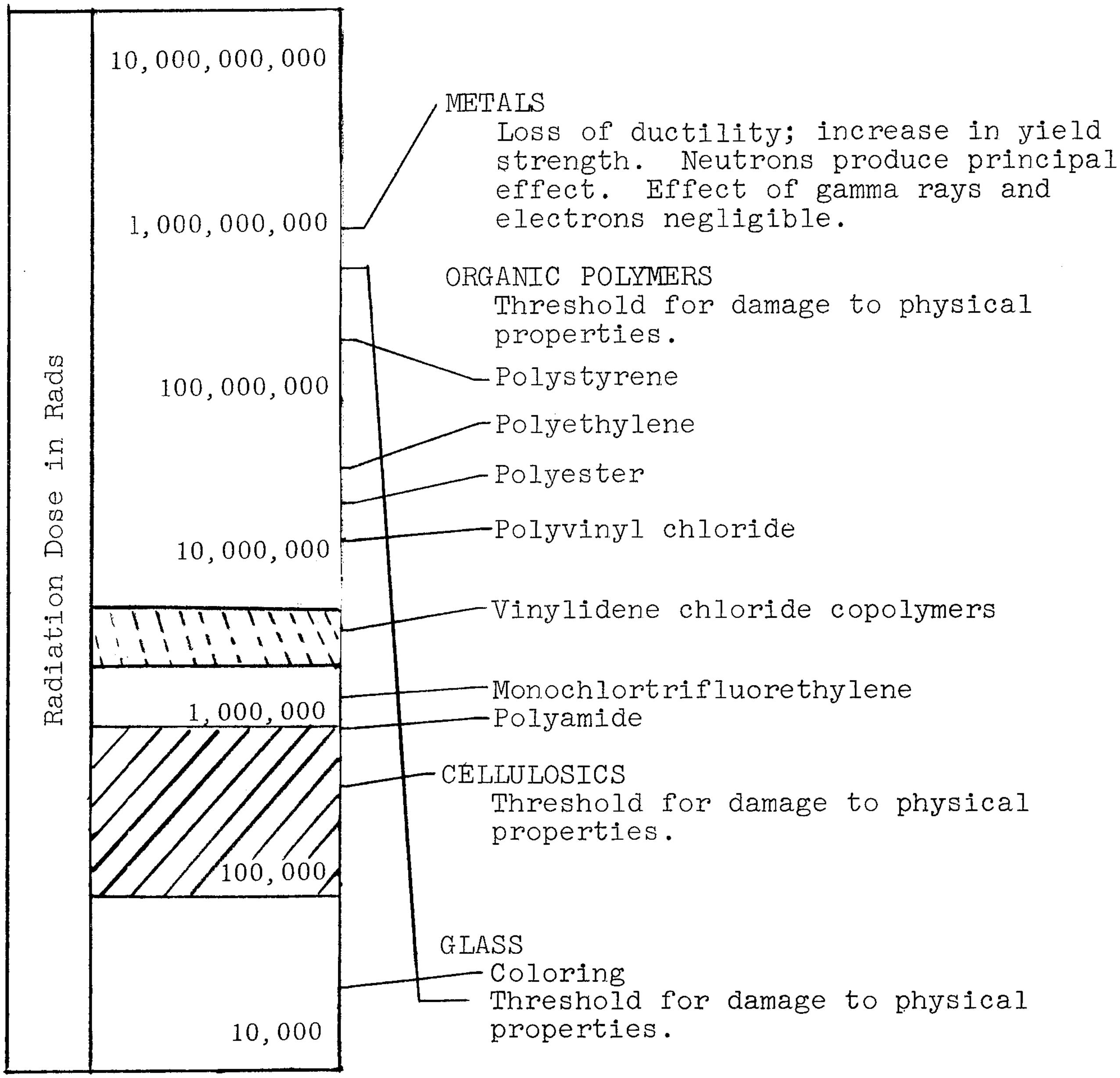
Fruits: Fresh strawberries, peaches, citrus fruits, grapes, and tomatoes.

Although it has been stated by many research workers in the field that radiation-pasteurization of foods will not demand excessive research and development efforts on the part of packaging manufacturers to supply adequate containers, we believe that a number of investigations and appraisals will be necessary prior to commercial feasibility of this new method of food preservation. This study was coordinated within Continental Can Company by the Central Research & Engineering Division. The Metal Container Division Research & Development Department, the General Packaging Research & Development Division, and the Hazel-Atlas Research & Development Department assisted in appraising the existing information on radiation effects on packaging materials and

applying this information to the package engineering requirements of ten selected food products.

The results of this effort is the outline of research and evaluation requirements contained in Part III of this study.

PART I



(There is a wide variation in effect of irradiation on various materials. Radiation levels are approximate.)

Radiation Pasteurization of Food (1 megarad or less)

Radiation Sterilization of Food (3 to 6 megarad)

Ref: (89, 339)

Fig. 1 Relative Sensitivity to Radiation of Principal Materials Used in Packaging.

PART I

A. EFFECTS OF RADIATION ON PRINCIPAL MATERIALS USED IN FOOD PACKAGING

Our objective has been to relate the literature in the field on a material basis rather than a container or design basis. The major material categories permit us to discuss radiation effects in a more generalized fashion with a firmer basis for extrapolation of known information derived from intensive experimental and theoretical work of the past twenty years.

In considering packaging materials for food items, one significant factor is the extensive utilization of organic polymers in virtually all package designs. In addition, of all materials used in packaging the effect of radiation on strength and organoleptic factors is more pronounced in organic polymers and cellulosic materials, and thus of greater concern, than in many other class of materials. It will be noted that the greatest emphasis has been placed on organic polymers in this report.

In Figure 1 the relative sensitivities of the principal materials to exposure and irradiation environment are presented as a guide post in considering specific materials used in food packaging.

In order to provide a background of information for evaluating the

impact of irradiation processing on specific food packaging materials, a brief descriptive review of radiation effects on major classes of packaging materials is presented in the following sections.

1. Cellulose

Cellulose as a natural polymer is crystalline and of high molecular weight. A wide variety of cellulose derivatives such as cellophane, rayon, and cellulose acetate is available as packaging material.

Upon exposure to high doses of radiation, cellulose and its derivatives suffer chain degradation and other chemical changes. These lead to a decrease of mechanical strength, an increase in solubility, and reduced viscosity of solutions.

Cellulose is one of the least stable materials when irradiated with ionizing radiation. (45, 81)

2. Glass

Ionizing radiation produces color-center formation in most types of glass. Irradiation produces free electrons in the glass which are either returned to the ions from which they came or are captured elsewhere at various trapping centers present in the glass. When the free electrons are trapped, color-center formation occurs, and one can readily observe the brown color present in the glass structure. In most cases heating at elevated temperature will anneal the glass and the color-centers will fade, allowing the glass to return to its colorless state.

Since, in most cases, the displaced electrons migrate back and recombine to form the normal state of an ionic compound, the effect of ionizing radiation is negligible on the chemical and physical properties of the material, except for the formation of color, at the radiation doses required for food sterilization or food pasteurization by irradiation.

The browning of glass at relatively low doses of radiation, in the region of radiation pasteurization doses and less, may require that additives be included in the glass melt to inhibit the formation of the brown coloration. (96, 299)

3. Metals

Radiation damage to metals may be divided into the two general groups, the effect of light particle irradiation including beta particles, gamma rays, x-rays and high energy electrons, and the effect of radiation with heavy particles such as alphas, neutrons and accelerated ions. In the field of food irradiation only light particle irradiation is considered of practical importance. The interaction of light particles with metals is almost entirely through ionization processes since these light particles have insufficient mass to transfer appreciable amounts of energy to a nucleus. In metallic bonding the outer shells of atomic electrons are held loosely to the nucleus and are free to migrate from atom to atom. Metal lattices of positive ions are surrounded by waves of electrons. The great mobility of the electron permits the dissipation of the energy absorbed by the metal as heat from the incident light particle irradiation which produces ionization , with negligible damage

to the structure of the metal atom.

In the region of interest for food irradiation with the proposed processes the heat generated in the metal of a food container would not be significant in its performance.

Thus the effect of radiation on the physical and mechanical properties of the metal is of negligible significance in its use as a material for food containers for irradiated food. (56, 339)

4. Organic Polymers

The studies of the effects of electromagnetic radiation and high energy electrons on the properties of organic polymers has had a rather extensive history. However, intensive evaluation of the effects of ionizing radiation on organic polymers has been performed subsequent to World War II. The technical literature is replete with thousands of references to the effects of ionizing radiation on organic polymers and it is beyond the scope of this survey to give more than a descriptive discussion of the phenomena involved.

Polymeric substances when exposed to gamma or beta radiation form free radicals in the solid materials resulting in cross-linking or chain scission or recombination. At the same time, hydrogen and other chemical species may be formed and, where irradiation is conducted in the presence of air, oxidation may also result. The net result is governed by the predominant reaction which is dependent upon the chemical structure of the polymer, stress, and environment.

The changes induced by large doses of radiation have a profound effect on polymeric materials. Cross-linking produced by radiation results in an increase of tensile strength and flexural strength, and a decrease in elongation, crystallinity and solubility. The shortening of the polymeric chain through scission results in a decrease in tensile and flexural strength.

Of particular importance in applying polymeric materials to packaging of radiation pasteurized foods is the influence of oxygen in the over-all reaction of the system. The presence of oxygen in all cases of all polymers is not well understood on a detailed basis and it is very probable that many of the polymers which show a preference for cross-linking may be degraded in molecular weight if the availability of oxygen is high. (45, 81, 369)

B. BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENTS

Introduction

Although intensive effort in evaluating radiation effects on materials has been pursued over a period of twenty years, the initiation of the Quartermaster Corps Radiation Preservation of Foods Program in 1953 established a comprehensive evaluation of packaging materials and packaging configurations for radiation treated foods. The results of that effort over the last seven to eight years forms the basis of this study.

As a result of that extensive program a number of review articles have appeared during the course of the last five years which discuss the influence of radiation preservation of foods on packaging materials. (115, 386, 387, 388)

In the work reported in the aforementioned reviews, the emphasis has been on materials which would receive radiation sterilization doses up to 6 megarads since the primary objective of the Quartermaster program was on food sterilization rather than pasteurization of foods by irradiation at doses of less than 1 megarad. In addition, of considerable importance in packaging technology, was the emphasis of that program on extended shelf life (one to two years) at room temperature. Generally, increased radiation doses lead to increased modifications or changes in materials

and increased temperature during storage will enhance the possibility of interaction between the packaging materials and the contained food.

Therefore, that work has been included in the report as a basis for extrapolation of data on the effects of radiation on packaging materials at radiopasteurization dosage levels.

Mode of Presenting the Literature Survey Tabulation

In Part I, A., the general effects of radiation on the principal classes of materials used in packaging were considered to provide a basis for detailed evaluation of packaging materials used in a food irradiation environment. In succeeding sections, summary tables and discussions are presented of the relative change in significant properties of specific packaging materials in food irradiation environments. The materials are arranged by normal food package manufacturing classifications listed below:

1. Paper -Rigid or flexible, with sizes, resins and organic coating materials.
2. Plastic -Rigid or flexible, alone or with organic coatings.
3. Metal -Rigid or flexible, alone or with organic coatings.
4. Laminates -Paper, foil, and plastic.
5. Glass
6. Wood
7. Adhesives and waxes
8. Colorants

Mode of Selection of Experimental Data Reported in the Literature

In selecting the data to be presented in the literature survey tabulation, the following factors were considered:

1. Type of "Contained" Food Environment

The importance of the total environment of the packaging material in food packaging was considered by the Can Manufacturers Institute in a petition to the Food and Drug Administration and subsequently published by the FDA as an official part of Food Additives Regulation 121.2514, "Resinous and Polymeric Coatings for Paper and Paperboard."

The use of the classification method of food and food constituents as the "contained" foods parameter permits the grouping of the results of a number of investigations of a specific packaging material into a data presentation of manageable proportions. Classes include:

I. Non-acid,aqueous product, usually containing salt or sugar or both (pH above 5.0).
Examples: Vegetables, olives, pancake and waffle batters.

II. Acidic, aqueous products, usually containing salt or sugar or both and including oil-in-water emulsions of low or high fat content.
Examples: Tomato products, fruits, jams, jellies, pickles, fruit juices, fruit ades and drinks, mayonnaise and some salad dressing.

III. Aqueous, acid or non-acid, products containing free oil or fat usually containing salt, and including water-in-oil emulsions of low or high fat content.
Examples: Meat and meat products, fish and marine products, some salad dressings, margarine.

In addition, air, sodium chloride solutions, and water were selected as representative model food environments for the products under consideration.

2. Type of Experimental Radiation Effects Data - Major emphasis was placed on experimental work performed on packaging materials in food environments.

3. Radiation Dose - In addition to experimental work performed at radiation-pasteurization doses (less than 1 megarad), work was included that was performed on packaging materials which were investigated at the radiation sterilization dose (3 to 6 megarad) since it represented a more severe requirement, in general, than the radiopasteurization requirements in terms of radiation dosage, shelf life, storage period, and temperature.

4. Radiation Sources - No specific effort has been made to indicate the source of radiation since any effect of the difference between gamma rays, x-rays, and energetic electrons is either insignificant or of less direct importance than the total dose absorbed.

5. Storage Period and Temperature - Emphasis was placed on data evaluating 30 to 60 day storage periods since this time scale more nearly represents the general region of interest in the lengthening of the shelf life of radiation-pasteurized foods. In virtually all cases, refrigeration temperatures (32^oF to 45^oF) are necessary for the ten selected food items. Very little definitive work has been performed at that temperature range with packaging materials which have been subjected to radiation-sterilization or pasteurization doses. Experimental work performed at high temperatures is included since it represented a conservative evaluation of packaging material performance.

TABLE 1

RELATIVE CHANGES IN SIGNIFICANT PROPERTIES OF PAPER PACKAGING MATERIALS (RIGID & FLEXIBLE, WITH RESINS AND ORGANIC COATINGS IN FOOD IRRADIATION ENVIRONMENTS

Material	STOR	Temp	RAD. DOSE	AIR Tensile Strength 1 2 3 4	AIR Elongation % 1 2 3 4	AIR Tear Strength 1 2 3 4	AIR MVT 1 2 3 4	AIR Organoleptic	AIR Optical	TYPE III FOODS Tensile Strength 1 2 3 4	TYPE III FOODS Elongation % 1 2 3 4	TYPE III FOODS Tear Strength 1 2 3 4	TYPE III FOODS MVT 1 2 3 4	TYPE III FOODS Optical
ALPHA Bleached, Paper	b	H	N	1		2			1					
	b	H	P	1		2			1					
	b	H	S	1		2			1					
GLASSINE Lacquered, 27#, H.S. Coated, Opaque	a	H	N			1	1–2		1					
	a	H	P			1	1–2		2					
	a	H	S			1	1–2		3					
GLASSINE Lacquered, 27#, H.S. Coated, Transparent	a	H	N			1			1					
	a	H	P			1			2					
	a	H	S			1			3					
GLASSINE Plain, 24#, Opaque	a	H	N			1			1					
	a	H	P			1			2					
	a	H	S			1			3					
GLASSINE Plain, 24#, Transparent	a	H	N			1			1					
	a	H	P			1			2					
	a	H	S			1			3					
GLASSINE Waxed, 31#, Cereal	a	H	N			1	1							
	a	H	P			1	1		3					
	a	H	S			1	1		4					
GLASSINE Waxed, (Potato Chip Bag)	b	H	N	1		1	2	1	1					
	b	H	P	1		1	1	1	1					
	b	H	S	1		1	1	1	1					
GLASSINE Wax Laminated, 47#	a	H	N			1	1		1					
	a	H	P			1	1		2					
	a	H	S			1	1		3					
KRAFT Bleached, 40# (Coated-0.5 mil P.E.)	a	H	N							1	1			
	a	H	P							1	1			
	a	H	S							1	1			
KRAFT Unbleached, 40# (Coated-1.0 mil P.E.)	o		N							2	1			
	o		P							2	1			
	o		S							2	1			
KRAFT Unbleached, 50# (Coated - 1.5 mil P.E.)	a	H	N							2	1			
	a	H	P							2	1			
	a	H	S							1	1			
KRAFT Unbleached, 50# (Coated - 2.0 mil P.E.)	o		N							2	1			
	o		P							2	1			
	o		S							2	1			
KRAFT Unbleached, Paper	b	H	N	1		2			1					
	b	H	P	1		2			1					
	b	H	S	1		2			1					
KRAFT Unbleached Cylinder Board	b	H	N	1–2		3			1					
	b	H	P	1–2		3			1					
	b	H	S	1–2		3			1					
KRAFT Wax coated, (Box Liner)	b	H	N	1		2	1		1					
	b	H	P	1		2	1		1					
	b	H	S	1		2	1		1					
PAPER (Coated both sides with Synthetic Rubber)	0		N							1	1	1	3	
	0		P							1	1	1	3	
	0		S							1	1	1	3	
RAG	b	H	N	1		2			1					
	b	H	P	1		2			1					
	b	H	S	1		2			1					
SULPHATE Bleached, Paper	b	H	N	1		2			1					
	b	H	P	1		2			1					
	b	H	S	1		2			1					
SULPHATE Bleached, Solid Board	b	H	N	1–3		3			1					
	b	H	P	1–3		3			1					
	b	H	S	1–3		3			1					
SULPHATE Bleached, Solid Board, (Coated)	b	H	N	1		3			1					
	b	H	P	1		3			1					
	b	H	S	1		3			1					
SULPHITE Bleached, Paper	b	H	N	1		1			1					
	b	H	P	1		1			1					
	b	H	S	1		1			1					
SULPHITE Bleached, Solid Board (Pigmented Casein Coated)	c	H	N	1–2		4			1					
	c	H	P	1–2		4			1					
	c	H	S	1–2		4			2					
SULPHITE Bleached, Solid Board	c	H	N	1		3			1					
	c	H	P	1		3			1					
	c	H	S	1		3			2					
SULPHITE Wax Coated, (Frozen Food Overwrap)	b	H	N	1		1	3		1					
	b	H	P	1		1	2		1					
	b	H	S	1		1	2		1					
SULPHITE Wax Coated, (Breadwrap)	b	H	N	1		1	3		1					
	b	H	P	1		1	3		1					
	b	H	S	1		1	3		1					

Storage (months)
0 - 0
a - 0 to 1,
b - 1 to 3
c - 3 to 12

Temp. (°F.)
R - 32 to 45
H - 72 to 100

Radiation Dose
N - No irradiation
P - Pasteurization Range (1 megarad or less)
S - Sterilization Range (3 to 6 megarad)

Tensile Strength-lb. /in. width
1. 1 - 25
2. 25 - 50
3. 50 - 75
4. 75 - 100

% Elongation
1. 15 - 50
2. 50 - 100
3. 100 - 300
4. 300 - 600

Tear Strength (gms.)
1. 5 - 50
2. 50 - 200
3. 200 - 600
4. 600 - Higher

MVT (gm. /24hr. /100 in.^{2} @100°F., 90% R.H. - unit thick.)
1. .000 - 0.5
2. .5 - 1.0
3. 1.0 - 5.0
4. 5.0 - Higher

Organoleptic (Off Flavor) (Off Odor)
1. Nil
2. Slight
3. Moderate

Optical
1. No change in opacity or color
2. Slight " " " " "
3. Small " " " " "
4. Large change in" " "

1. Paper-Rigid or flexible, alone or with sizes, resins and organic coatings

The experimental studies reviewed in this survey indicate that no significant changes in mechanical or chemical properties of paper packaging materials occur as a result of irradiation at radiation-pasteurization doses in the presence of air or in contact with food if good packaging practice is used in selection of the specific paper type for the food.

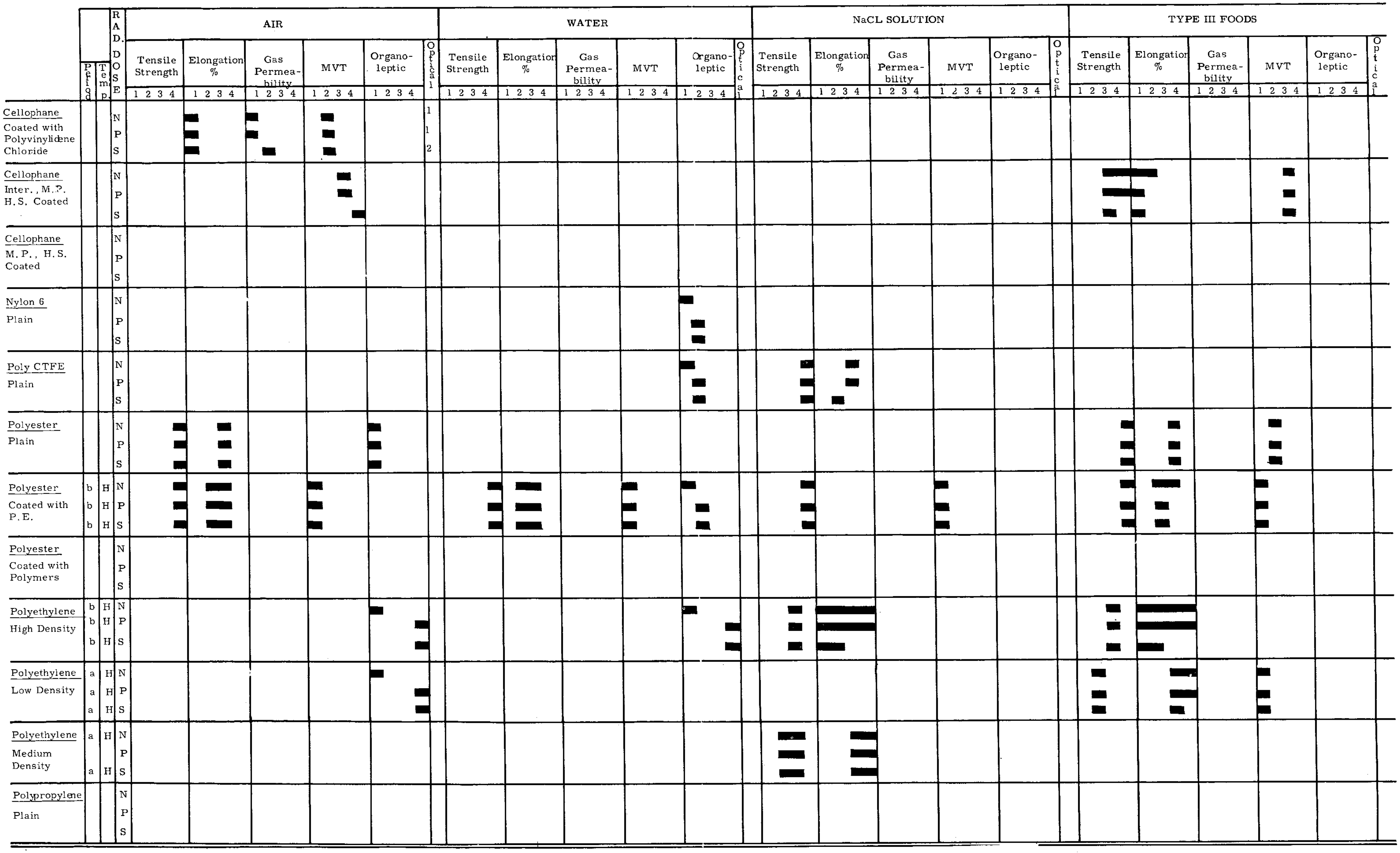
Dyes used in glassine papers may tend to fade slightly at radiation doses less than 1 megarad.

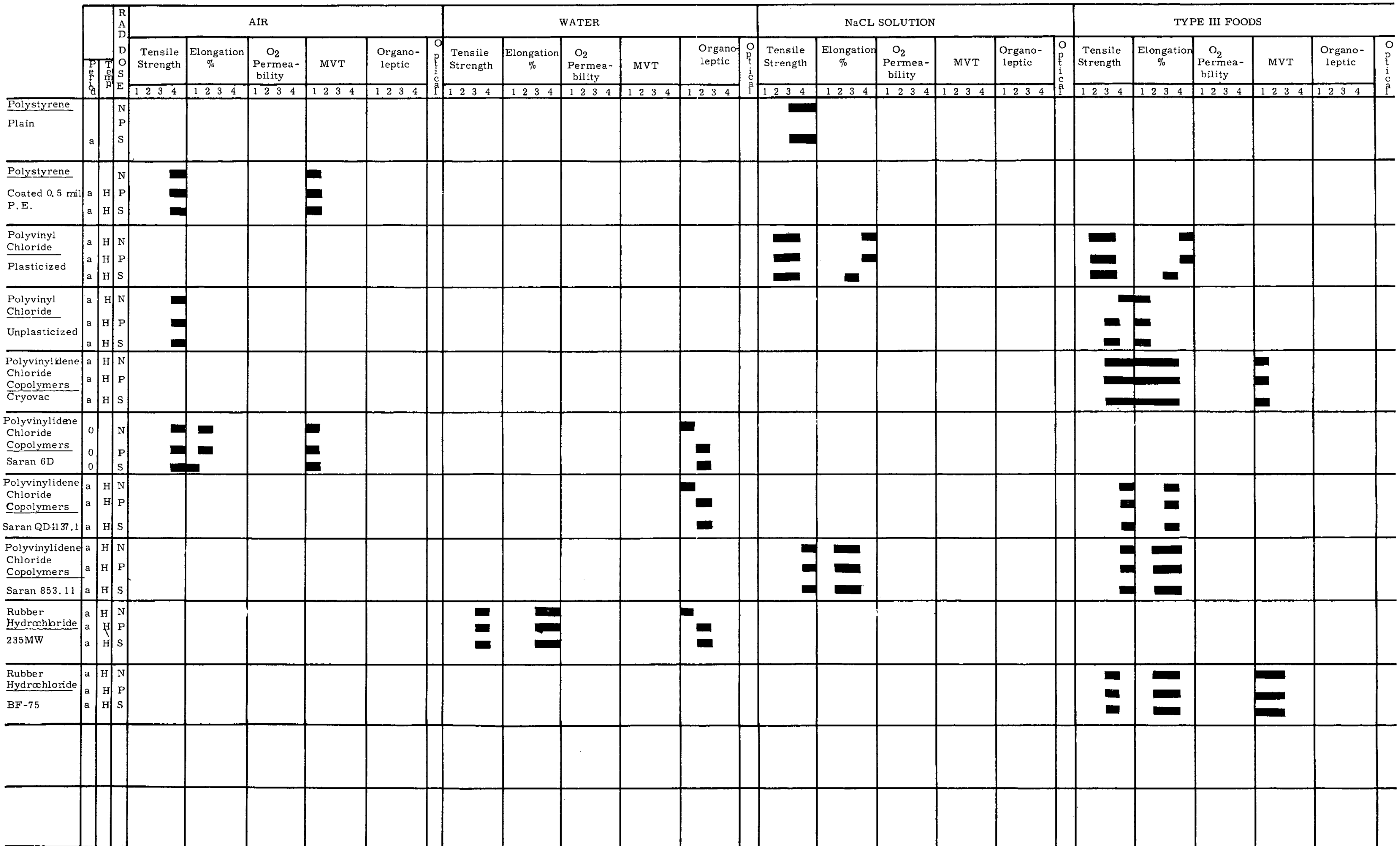
Studies on model food systems have reported off-flavor development as a result of irradiation in polymer-coated papers; the nature and extent of the off-flavor is a function of the specific polymer used. However, some polymers were preferred to paper in scoring flavor preferences for radiation-pasteurized fruits and vegetables packaged before irradiation. (94, 117, 118, 201, 310, 316, 343, 437)

See Table 1.

TABLE 2

CHANGES IN SIGNIFICANT PROPERTIES OF PLASTIC PACKAGING MATERIALS (RIGID & FLEXIBLE), ALONE OR WITH ORGANIC COATINGS IN FOOD IRRADIATION ENVIRONMENTS





	Storage (months)	Temp. (°F.)	Radiation Dose	Tensile Strength (p.s.i.)	% Elongation	O_2 Permeability (cc/100 in.^{2}/day @ atmos. pres. -unit thick.)	MVT (gm./24 hr./100 in.^{2} @ 100°F., 90% R.H. -unit thick.)	Organoleptic (Off Flavor) (Off Odor)	Optical
▬ Data derived from survey	0 - 0	R - 32 to 45	N - No irradiation	1. 1000 - 2500	1. 15- 50	1. 0 - 0.5	1. .000 - 0.5	1. Nil	1. No change in opacity or color
Probable behavior based on related data as interpreted by CCC	a - 0 to 1	H - 72 to 100	P - Pasteurization (1 megarad or less)	2. 2500 - 7000	2. 50- 100	2. 0.5 - 2.0	2. .5 - 1.0	2. Slight	2. Slight " " " " "
	b - 1 to 3		S - Sterilization Range (3 to 6 megarad)	3. 7000 - 12000	3. 100- 300	3. 2.0 - 5.0	3. 1.0 - 5.0	3. Moderate	3. Small " " " " "
	c - 3 to 12			4. 12000 - higher	4. 300- 600	4. 5.0 - higher	4. 5.0 - higher		4. Large change in" " "

2. Plastic - Rigid or flexible, alone or with organic coatings

The mechanical and chemical properties of plastic packaging materials are not significantly altered in the presence of air or in contact with food during irradiation at 1 megarad or less.

In surveying the literature on the performance of plastic packaging materials for radiation-pasteurized foods, the possible influence of plastic packaging materials on the organoleptic acceptability of the packaged food is considered as the only significant functional aspect of concern.

In selecting a specific plastic packaging material for packaging a specific food item, established package engineering practices can be followed with the exception that off-flavor and off-odor contributions from irradiated polymeric materials vary markedly from one polymer type to another. In addition, considerable variation can exist within one polymer type depending upon the method of manufacture, additives used, percentage of virgin material, age and storage environment.

A detailed discussion of observations and measurements of off-odor and off-flavor is included in Part III A5. (38, 39, 45, 115, 116, 117, 118, 166, 197, 201, 206, 282, 286, 316, 338, 389, 395).

See Table 2

TABLE 3

RELATIVE CHANGES IN SIGNIFICANT CHARACTERISTICS OF METAL PACKAGING MATERIALS (RIGID & FLEXIBLE), ALONE OR WITH ORGANIC COATINGS IN FOOD IRRADIATION ENVIRONMENTS

	STORAGE Period	STORAGE Temp.	RAD. DOSE	TYPE I FOODS Staining 1 2 3 4	TYPE I FOODS Loss of Adhesion 1 2 3 4	TYPE I FOODS Loss of Flexibility 1 2 3 4	TYPE I FOODS Corrosion 1 2 3 4	TYPE I FOODS Blistering 1 2 3 4	TYPE I FOODS S.C.	TYPE II FOODS Staining 1 2 3 4	TYPE II FOODS Loss of Adhesion 1 2 3 4	TYPE II FOODS Loss of Flexibility 1 2 3 4	TYPE II FOODS Corrosion 1 2 3 4	TYPE II FOODS Blistering 1 2 3 4	TYPE II FOODS S.C.	TYPE III FOODS Staining 1 2 3 4	TYPE III FOODS Loss of Adhesion 1 2 3 4	TYPE III FOODS Loss of Flexibility 1 2 3 4	TYPE III FOODS Corrosion 1 2 3 4	TYPE III FOODS Blistering 1 2 3 4	TYPE III FOODS S.C.
Aluminum, Rigid, Vinyl-Phenolic Enameled			N	▨ 1	▨ 1		▨ 1			▨ 1	▨ 1		▨ 1			▨ 1	▨ 1		▨ 1		
			P	▨ 1	▨ 1		▨ 1			▨ 1	▨ 1		▨ 1			▨ 1	▨ 1		▨ 1		
	c	H	S	■ 1	■ 1		■ 1		S	■ 1	■ 1		■ 1		S	■ 1	■ 1		■ 1		S
Aluminum, Rigid, Plain			N																		
			P																		
	c	H	S	■ 3			■ 3		S							■ 3			■ 3		S
Tinplate, Rigid, Electrolytic, Oleoresinous Enameled			N							▨ 1	▨ 1			▨ 1							
			P							▨ 1	▨ 1			▨ 1							
	c	H	S							■ 1	■ 1	■ 3	■ 2	■ 1							
Tinplate, Rigid, Electrolytic, Phenolic Enameled			N													▨ 1	▨ 1		▨ 1	▨ 1	
			P													▨ 1	▨ 1		▨ 1	▨ 1	
	c	H	S													■ 1	■ 1	■ 2	■ 2	■ 1	
Tinplate, Rigid, Electrolytic, Epoxy-Phenolic Enameled			N													▨ 1	▨ 1		▨ 1	▨ 1	
			P													▨ 1	▨ 1		▨ 1	▨ 1	
	c	H	S													■ 1	■ 1		■ 1	■ 1	
Tinplate, Rigid, Electrolytic, Polybutadiene Enameled			N							▨ 1	▨ 1		▨ 1	▨ 1							
			P							▨ 1	▨ 1		▨ 1	▨ 1							
	c	H	S							■ 1	■ 1	■ 2	■ 1	■ 1							
Tinplate, Rigid, Electrolytic, Polybutadiene Enameled (Zinc Paste Added)			N													▨ 1	▨ 1		▨ 1	▨ 1	
			P													▨ 1	▨ 1		▨ 1	▨ 1	
	c	H	S													■ 1	■ 1	■ 2	■ 1	■ 1	
Tinplate, Rigid, Electrolytic, Epoxy-Phenolic Enameled (Zinc Paste Added)			N							▨ 1	▨ 1	▨ 1	▨ 1	▨ 1		▨ 1	▨ 1	▨ 1	▨ 1	▨ 1	
			P							▨ 1	▨ 1	▨ 1	▨ 1	▨ 1		▨ 1	▨ 1	▨ 1	▨ 1	▨ 1	
	c	H	S							■ 1	■ 1	■ 1	■ 1	■ 1		■ 1	■ 1	■ 1	■ 1	■ 1	S
Tinplate, Rigid, Electrolytic, Oleoresinous (Zinc Paste Added)			N													▨ 1	▨ 1	▨ 1	▨ 1		
			P													▨ 1	▨ 1	▨ 1	▨ 1		
	c	H	S													■ 2	■ 2	■ 2	■ 2	■ 1	
Tinplate, Rigid, Electrolytic, Epoxy-Ester (Al. Added)			N													▨ 1	▨ 1		▨ 1	▨ 1	
			P													▨ 1	▨ 1		▨ 1	▨ 1	
	c	H	S													■ 1	■ 1		■ 1	■ 1	
Tinplate, Hot Dipped, Epoxy-Phenolic Enameled			N							▨ 1		▨ 1	▨ 1	▨ 1							
			P							▨ 1		▨ 1	▨ 1	▨ 1							
	c	H	S							■ 1		■ 1	■ 1	■ 1							
Tinplate, Hot Dipped, Oleoresinous Enameled			N							▨ 1	▨ 1		▨ 1								
			P							▨ 1	▨ 1		▨ 1								
	c	H	S							■ 1	■ 1	■ 2	■ 1	■ 2							
Tinplate, Hot Dipped, Polybutadiene			N							▨ 1	▨ 1		▨ 1	▨ 1							
			P							▨ 1	▨ 1		▨ 1	▨ 1							
	c	H	S							■ 1	■ 1	■ 2	■ 1	■ 1							

■ Data derived from survey

▨ Probable behavior based on related data as interpreted by CCC.

Storage (months)
0 - 0
a - 0 to 1
b - 1 to 3
c - 3 to 12

Temp. (°F.)
R - 32 to 45
H - 72 to 100

Radiation Dose
N - No irradiation
P - Pasteurization (1 megarad or less)
S - Sterilization Range (3 to 6 megarad)

1. No change in performance.
2. Very slight change in performance.
3. Slight change in performance.
4. Poor performance

S.C. (Sealing Compound)
S - Satisfactory performance.
U - Unsatisfactory performance.

3. Metal - Rigid or flexible, alone or with organic coatings

The structural integrity of metals used in food containers is unaltered at food irradiation doses. The performance of metal containers for irradiated foods is concerned with the possible deleterious effects of the combined effects of irradiation, food substances, and storage on the coated or plain metal surfaces.

A limited number of studies of coated or uncoated metal containers has been conducted to evaluate the performance of these types of food packages at radiopasteurization doses.

Radiation-pasteurized fruits and vegetables packaged in rigid, vented, unlined tinplate container, generally were more acceptable than those tinplate containers lined with either aluminum foil, paper, or plastic films.

The results of studies conducted on a variety of food products, which were radiation-sterilized, indicate that rigid, coated metal containers will perform satisfactory at radiation-pasteurization doses for those food products requiring a sealed container. As in present rigid metal can usage for conventionally processed foods, proper selection of the inside enamel or coatings plays a significant role in over-all performance of the can. Again, extrapolating the work performed at radiation-sterilization doses to the radiation-pasteurization dose level, presently used can enamels specified for similar conventionally processed foods should perform satisfactory for radiation-pasteurized foods.

In the case of radiation-pasteurized foods which would require a solution surrounding the food, determination of the proper headspace volume may be necessary since irradiation will evolve gases from the solution and the food.

No adverse comments on the possible contribution of coated or uncoated metal containers to the organoleptic acceptability of the food were found in the survey. It has been reported that distilled water irradiated in rigid, uncoated aluminum cans contained a white, flaky substance but the distilled water did not have an off-flavor. However, no model system studies using distilled water for off-flavor evaluation were found for coated, rigid, metal cans as were performed on a variety of plastic and paper films. (39,173, 278, 279, 281, 316, 340)

See Table 3.

TABLE 4

RELATIVE CHANGES IN SIGNIFICANT PROPERTIES OF LAMINATES - PAPER, FOIL, AND PLASTIC PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENTS

	Period	Temp	RAD. DOSE	AIR: Tensile Strength 1 2 3 4	AIR: Elongation % 1 2 3 4	AIR: O2 Permea-bility 1 2 3 4	AIR: MVT 1 2 3 4	AIR: Organo-leptic 1 2 3 4	AIR: Optical	WATER: Tensile Strength 1 2 3 4	WATER: Elongation % 1 2 3 4	WATER: O2 Permea-bility 1 2 3 4	WATER: MVT 1 2 3 4	WATER: Organo-leptic 1 2 3 4	WATER: Optical	NaCL SOLUTION: Tensile Strength 1 2 3 4	NaCL SOLUTION: Elongation % 1 2 3 4	NaCL SOLUTION: O2 Permea-bility 1 2 3 4	NaCL SOLUTION: MVT 1 2 3 4	NaCL SOLUTION: Organo-leptic 1 2 3 4	NaCL SOLUTION: Optical	TYPE III FOODS: Tensile Strength 1 2 3 4	TYPE III FOODS: Elongation % 1 2 3 4	TYPE III FOODS: O2 Permea-bility 1 2 3 4	TYPE III FOODS: MVT 1 2 3 4	TYPE III FOODS: Organo-leptic 1 2 3 4	TYPE III FOODS: Optical
Polyester(P. E. coated) Al. Foil-Paper (25# Plastized)	a	H	N																								
			P																								
	a	H	S																								
Polyethylene-Al. Foil-Paper(coated)	0		N																								
	0		P																								
	0		S																								
Polyethylene-Al. Foil-Polyester-Polyethylene	b	H	N																								
	b	H	P																								
	b	H	S																								
Polyethylene-Cellophane	b	H	N																								
	b	H	P																								
	b	H	S																								
Polyethylene-Polyester	b	H	N																								
	b	H	P																								
	b	H	S																								
Polyethylene-Polyvinylidene Chloride	b	H	N																								
	b	H	P																								
	b	H	S																								
KRAFT, Unbleached,40# Al. Foil, Rubber Hydro-Chloride	c	H	N																								
	c	H	P																								
KRAFT, Unbleached, 40#-Al. Foil, Polyvinyl Chloride	c	H	N																								
	c	H	P																								
KRAFT, Unbleached, 40#-Al. Foil, Polyvinylidene Chloride Copolymers	c	H	N																								
	c	H	P																								
			N																								
			P																								
			S																								
			N																								
			P																								
			S																								
			N																								
			P																								
			S																								

■ Data derived from survey

▨ Probable behavior based on related data as interpreted by CCC.

Storage(months)
0 - 0
a - 0 to 1
b - 1 to 3
c - 3 to 12

Temp. ($^oF.$)
R - 32 to 45
H - 72 to 100

Radiation Dose
N - No irradiation
P - Pasteurization (1 megarad or less)
S - Sterilization Range (3 to 6 megarad)

Tensile Strength (lb. /in. width)
1. 5 - 10
2. 10 - 15
3. 15 - 20
4. 20 - higher

% Elongation
1. 15 - 50
2. 50 - 100
3. 100 - 300
4. 300 - 600

O_2 Permeability (cc/100 in.^{2}/day @ atmos. pres. -unit thick.)
1. 0 - 0.5
2. 0.5 - 2.0
3. 2.0 - 5.0
4. 5.0 - higher

MVT (gm./24 hr./100 in.^{2} @ 100°F., 90% R.H. -unit thick.)
1. .000 - .02
2. .02 - .08
3. .08 - .14
4. .14 - higher

Organoleptic (Off Flavor) (Off Odor)
1. Nil
2. Slight
3. Moderate

Optical
1. No change in opacity or color
2. Slight " " " " "
3. Small " " " " "
4. Large change in " " "

4. Laminates - Paper, foil, and plastic

Various laminated materials may be used when packaging irradiated foods. A typical laminate consists of a plastic film on the interior side, a layer of thin aluminum foil, and an exterior layer of paper and/or plastic film. The purpose of the interior plastic film is to provide a means of heat sealing and to protect the aluminum foil from chemical attack. The aluminum foil provides the required moisture and oxygen barrier. The paper provides the mechanical strength of the laminated food package. The effect that high dosages of radiation might have on laminates depends upon the individual components and the adhesives used in bonding the various plys.

At radiation-pasteurization doses, the mechanical and chemical properties of laminates are not severely altered.

Since plastic films or coatings are usually present as one or more plies of the laminate, the possible introduction of an organoleptic contribution to the food is a concern. Part III reviews this aspect in detail. (90, 117, 118, 201, 389)

See Table 4.

TABLE 5

RELATIVE CHANGES IN SIGNIFICANT PROPERTIES OF GLASS PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENTS

	RAD. DOSE	AIR						TYPE III FOODS					
		Strength		Chem. Durability		Color		Strength		Chem. Durability		Color	
		1	2	1	2	1	2	1	2	1	2	1	2
BOROSILICATE	N		◪		◪		◪		◪		◪		◪
	P		◪		◪	◪			◪		◪	◪	
	S		◪		◪	◪			◪		◪	◪	
SODA-LIME	N		◪		◪		◪		◪		◪		◪
	P		◪		◪	◪			◪		◪	◪	
	S		◪		◪	◪			◪		◪	◪	

■ Data derived from survey

◪ Probable behavior based on related data as interpreted by CCC.

Radiation Dose
N - No irradiation
P - Pasteurization Range (1 megarad or less)
S - Sterilization Range (3 to 6 megarad)

1. Unsatisfactory performance.
2. Satisfactory performance.

5. Glass

Although several extensive investigations of the effects of irradiation on many types of glasses have been performed, very little work or data are available on the effects of irradiation on glass used as a food container.

Studies conducted on commercial types of borosilicate, soda lime (flint) and lead glasses showed that irradiation with 2 Mev electrons produced no important effects on the flexural strength, chemical durability, density, electrical resistivity or heat of solution of these commercial glasses. Olive brown discoloration of the glass was noted in the irradiation specimens. This discoloration may be avoided by the addition of cerium to the glass melt but is a costly method for the present time.

Because of its fragile nature and weight glass does not readily lend itself to the packaging requirements for military feeding. Consequently the Quartermaster Corps, which has reported a good portion of the work on packaging materials for irradiated foods, has not sponsored much work on glass containers.

Although absorption of gamma irradiation is minimal in glass, irradiation in typical plastic or metal containers is slightly more efficient. In the case of gamma irradiation, glass containers would more efficiently utilize the radiant energy. However, they would be less efficient than typical plastic or metal containers. (26, 29, 96, 231, 386) See Table 5.

TABLE 6

RELATIVE CHANGES IN SIGNIFICANT PROPERTIES OF WOOD PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENTS

	RAD DOSE	AIR: Resistance to Compression 1	AIR: Resistance to Compression 2	AIR: Resistance to Splitting 1	AIR: Resistance to Splitting 2	AIR: Resistance to Static Bend 1	AIR: Resistance to Static Bend 2
ASH	P		▨		▨		▨
	S		▨		▨		▨
BEECH	P		▨		▨		▨
	S		▨		▨		▨
PINE	P		▨		▨		▨
	S		▨		▨		▨

■ Data derived from survey

▨ Probable behavior based on related data as interpreted by CCC.

Radiation Dose
N - No irradiation
P - Pasteurization Range (1 megarad or less)
S - Sterilization Range (3 to 6 megarad)

1. Large change in strength.
2. Minimal change in strength.

6. Wood

This survey on packaging materials has not found any work in which wood has served either as a primary or secondary container for irradiated foods.

However, measurements of the effects of radiation on basswood, ash, beech, and pine indicate that no significant changes in physical or chemical properties occur at radiation-pasteurization doses.

It is anticipated that wood as a packaging material will perform satisfactorily for radiation pasteurized foods (188, 204).

See Table 6.

TABLE 7

RELATIVE CHANGES IN SIGNIFICANT CHARACTERISTICS OF ADHESIVES AND WAXES IN FOOD IRRADIATION ENVIRONMENTS

	STORAGE		RAD DOSES	AIR															
				Melting Point (°F.)				Viscosity (Centipoise)				Penetration (X0.00001")				Seal Strength (gms /in.)			
	Period	Temp		135-155	155-165	165-175	175-181	3 - 10	10 - 25	25 - 100	100-4000	0.5 - 5	5 - 15	15 - 75	75 - 6000	5 - 10	10 - 35	35 - 50	50 - 75
WAX - Blending Microcrystalline (155°F.)	b	H	N		■				■						■				■
	b	H	P		■				■						■				■
	b	H	S		■				■						■				■
WAX - Fully refined Paraffin (138-140°F.)	b	H	N	■				■					■			■			
	b	H	P	■				■					■			■			
	b	H	S	■				■					■			■			
WAX - Fully refined Butyl Rubber	b	H	N				■			■					■			■	
	b	H	P				■			■					■			■	
	b	H	S				■			■					■			■	
WAX - Laminating Microcrystalline	b	H	N		■				■						■		■		
	b	H	P		■				■						■		■		
	b	H	S		■				■						■		■		
WAX - Semiparaffin (150°F.)	b	H	N		■			■						■		■			
	b	H	P		■			■						■		■			
	b	H	S		■			■						■		■			
WAX - Semiparaffin - Polyethylene	b	H	N			■					■	■					■		
	b	H	P			■					■	■					■		
	b	H	S			■					■		■				■		
WAX - Semiparaffin - Blending Microcrystalline-Polyethylene	b	H	N			■				■		■					■		
	b	H	P			■				■		■					■		
	b	H	S			■				■		■					■		

Storage (months)	Temp. (°F.)	Radiation Dose
0 - 0	R - 32 to 45	N - No irradiation
a - 0 to 1	H - 72 to 100	P - Pasteurization (1 megarad or less)
b - 1 to 3		S - Sterilization Range (3 to 6 megarad)
c - 3 to 12		

7. Adhesives and waxes

Investigation of radiation effects on waxes used in conjunction with other packaging materials reported no significant change in properties at radiation doses of less than 1 megarad in the presence of air. At the radiation sterilization level, increased viscosities were noted for those wax blends containing polyethylene and butyl rubber. Storage of irradiated samples for periods up to six months did not alter their characteristics. No noticeable odor development in the waxes was found. (343)

See Table 7.

TABLE 8

RELATIVE CHANGES IN SIGNIFICANT PROPERTIES OF COLORANTS USED IN PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENTS

	RADDOSE	AIR: Color Change 1	AIR: Color Change 2
DYESTUFFS* Used as Pigments in Polyethylene	N		▨
	P		▨
	S		▨
LETTERPRESS INKS	N		▨
	P		▨
	S		▨
LITHOGRAPHIC INKS	N		▨
	P		▨
	S		▨
FLEXOGRAPHIC INKS	N		▨
	P		▨
	S		▨
GRAVURE INKS	N		▨
	P		▨
	S		▨

■ Data derived from survey

▨ Probable behavior based on related data as interpreted by CCC

Radiation Dose
N - No irradiation
P - Pasteurization Range (1 megarad or less)
S - Sterilization Range (3 to 6 megarad)

1. Change in Color.
2. No change in Color.

* List of Dyestuffs:
Vulcafor Violet 2RS
Vulcafor Claret YS
Vulcafor Blue GNS
Vulcafor Fast Blue BS
Vulcafor Royal Blue AS
Vulcafor Red 2 RS
Vynamon Blue AS
Vynamon Violet RS
Vynamon Violet BS
Orasol Blue
Alkali Blue
Eriochrome Black T
Erio Green B
Eosin Yellowish High Conc.
Auramine O 150%
Tinopal AN
Malachite Green Oxalate
Sudal III
Fluorescein
Methylene Blue
Indigo Carmine
Naphthalene Black
Rhodamine G
Dichlorofluorescein

8. Colorants

Packaging colorants include inks and materials incorporated either in the body or in surface coatings on plastics, paper, etc. A limited amount of directly applicable experimental work on colorants used in conjunction with packaging was found in this survey.

Most commercial grades of ink used for printing and decorating of packaging grade fibreboard are resistant to color change at radiation-pasteurization and sterilization doses.

A variety of dyes and pigments used in coloring polyethylene (see Table 8) show no color change at radiation doses as high as 15 megarad.

a. Inorganic Pigments - Natural or Manufactured

Generally these have good light and heat resistance. With the possible exception of carbon and other surface active materials one would not expect that low radiation-pasteurization doses would produce chemical or color changes in them or that they would, in turn, adversely affect a polymer.

Irradiated metal finishes (pigmented melamine non-oxidizing alkyd) at 7.5 megarad and higher doses exhibit greater hardness and specular gloss. Color changes are noted in a few formulations. At radiation-pasteurization doses, it is unlikely that significant changes in these finishes would be found.

b. Organic Dyes

There are reputedly over 10,000 organic dyes, practically all of which are affected to some extent by light, heat and probably by radiation. When incorporated in polymers it is unlikely that either the dye or the polymer will be adversely affected by the presence of the other insofar as their response to radiation is concerned. This statement has not, however, been verified experimentally.

Dyes used in glassine papers are markedly changed in color at radiation-sterilization doses. In the radiation-pasteurization dose region, however, it is likely that color changes are of borderline significance.

Blue cellophane, incorporating an azo dye, is used in radiation dosage measurements from 10^5 to 10^7 rad. The change in transmittance is measured at 6550A. With a radiation dose of 1 megarad, the change in transmittance is approximately 1-1/2%, and at half a megarad is less than 1%. Thus, it is reasonable to assume that many azo dyes will perform satisfactory in packaging materials.

c. Lake Pigments (Dyes Precipitated onto Aluminum Hydrate)

Lake pigments are somewhat more stable than organic dyes to heat, light, and radiation when used in inks and in polymer films or coatings. Polymers may be less affected by radiation due to the presence of these lake pigments because each colored and somewhat opaque aluminum hydrate particle protects the underlying polymer and the pigment particles to some extent.

d. Blends of Natural or Manufactured Inorganic Pigments and Lake Pigments

It is reasonable to expect that the protective action of lake pigments observed in (c) above will be further enhanced by the more opaque inorganic pigments. It seems unlikely that there is a destructive interaction between inorganic and lake pigments or a polymer breakdown because of their inclusion. This statement has not, however, been verified experimentally.

PART II

TABLE 9

PRESENT PRACTICES IN THE MARKETING OF THE SELECTED REFRIGERATED FISHERY PRODUCTS

		1960 DOMESTIC MARKET								1960 IMPORT MARKET		CONTAINER TYPES USED FOR FRESH OR FROZEN MARKET					
		Producing Region		Annual Catch	Packaged Market	Dollar Value 10^6\$/yr.		% Catch Prepackaged		Fresh & Frozen Product		Material					
Sea Food	Ref. No.	Area	%	10^6#/yr.	10^6#/yr.	Ex-vessel	Packaged	Fresh	Frozen	10^6#/yr.	Country	Type	Specific	Coating	Style	Size	Marketed As
CLAMS (Shucked) (35%)	423 277 6 381 421 383 278	New Eng. Mid. Atl. Chesapeake	24 60 12	48.6 (Meat)	19.2	11.5	8.8	(Total) 48		1.9	Japan Mexico	Metal Paper Metal	Tinplate Kraft Tinplate	C-Enamel Wax C-Enamel	Can Carton Can	1 pt.; 1 qt.; 4 lb 8 lb 40 lb 1, 5 lb 1 gal.	Fresh Frozen
CRAB (Cooked) (48%)	423 278 6 381 421 383 277	Mid. Atl. So. Atl. Gulf Pacific Chesapeake Alaska	5 15 10 25 34 10	205.6	19.2	15.6	18.2	(Total) 23.3		0.26	British Columbia	Metal Paper Plastic Metal	Tinplate Kraft Cellophane Tinplate	C-Enamel Waxed - C-Enamel	Can Carton Bag Can	1; 5 lb 6, 12 oz.; 3, 5, 10 lb waxed, carton, overwrap 1/2, 1 lb.	Fresh Frozen
FLOUNDER (Fillets) (54%)	423 6 278 287 381 421 383 277	New Eng. Md. Atl. Pacific	46 9 41	130.3	24.2	13	9.2	22.7	15.5	18.7	Canada Iceland	Metal Paper Plastic Paper Plastic	Tinplate Parchment Cellophane Parchment Cellophane	C-Enamel - - - -	Can Wrap Wrap Wrap Wrap	10, 15, 20, 25, 30 lb 5-20 lb waxed cartons, or 30 lb. ccans 1-30 lb. waxed cartons, or tray with overwrap, corrugated or wooden boxes.	Fresh Frozen
HADDOCK (Fillets) (48%)	336 287 423 421 6 277 381 278 383	New Eng.	99	118.6	39.4	9.4	11.8	34.8	26.7	21.9	Canada Iceland	Metal Paper Plastic Paper Plastic	Tinplate Parchment Cellophane Parchment Cellophane	C-Enamel - - - -	Can Wrap Wrap Wrap Wrap	10, 15, 20, 25, 30 lb 5-20 lb waxed cartons, or 30 lb. cans 1-30 lb. waxed cartons, or tray with overwrap, corrugated or wooden boxes.	Fresh Frozen
SHRIMP 1. headless (57%) 2. raw, peeled (37%) 3. breaded (50%) 4. cooked & peeled (24%)	52 6 421 277 278 284 381 383	So. Atl. Gulf Pacific	15 82 2	248.7	119.9 1. 58.2 2. 9.3 3. 51.0 4. 1.4	66.9	105.1	(Total) 96		113	Mexico Panama	Wood Metal Paper Paper Metal Paper	Fir Tinplate Kraft Kraft Tinplate Kraft	Liner C-Enamel Wax Wax C-Enamel Wax	Box Can Carton Carton Can Carton	100 lb 6, 12 oz. 1, 2-1/2, 5, 10 lb 8, 10, 12 oz.; 2-1/2, 4, 5 lb 4, 8, 12 oz ; 1 gal. 1, 5 lb	1. Fresh 2. Frozen 3. Frozen 4. Fresh & Frozen

		COLD STORAGE LIFE (DAYS)				Geographical Distribution of Sales-% of Total Market						Chemical Evanulation-Acceptable Level					
												Vol. Red. Subst. (µeqs./5 ml.)		Total Vol. Nit. (mg./100 ml.)		Trimethylamine Nit. (mg. %)	
Sea Food	Ref. No.	0°F.	32°F.	Retail Temp. °F.	Storage Life Days	Eastern	Central	Pacific	Type of Spoilage	Percent Retail Spoilage	Dollar Loss To Spoilage (10^6\$/yr.)	Init.	Max.	Init.	Max.	Init.	Max.
CLAMS	6 114	270	14	40-45	3	-	-	-	Bacterial Enzymatic	10	0.9	3	15	3	15	0	2
CRAB	6 114	180	5-7	40-45	2	-	-	-	Bacterial Oxidative	5	0.9	3	15	3	15	0	2
FLOUNDER	287 6 233 74 114	270	6-9	40-45	3	-	-	-	Bacterial Chemical	15	1.4	2	15	2	15	0	2
HADDOCK	287 6 233 74 114	270	5-12	40-45	3	-	-	-	Bacterial Chemical	20	2.4	2	15	2	15	0	2
SHRIMP	6 284 114 221	180	7-10	40-45	3	-	-	-	Bacterial Chemical	12	12.6	6	15	6	15	0	2
(Fresh Whole)				35-42	4-5												
(Fresh Headless)				35-42	12-15												
(Refrig. Cooked)				35-42	10												

PART II

A. PRESENT PRACTICES IN THE PACKAGING OF THE SELECTED REFRIGERATED FISHERY PRODUCTS

Fishery products are among the most perishable of foods. It is necessary, therefore, to process and refrigerate them immediately to retain their fresh quality. This consideration largely determines present packaging and distribution practices. Table 9 gives the storage life of fishery products held at refrigerated temperatures.

The major causes of spoilage are:

(a) Psychrophilic bacteria

(b) Chemical reactions such as oxidation which result in off-flavors

(c) Enzymatic reactions which cause discoloration and off-flavors

(d) Improper storage temperature and humidity

(e) Improper packaging

Bacterial growth and improper storage are the most important.

A recent U. S. Department of the Interior survey of the New England fish industry showed that the average housewife buys

fish in the following forms:

Fresh	39%
Canned	25
Frozen uncooked	24
Frozen precooked	12

The survey also showed that: (a) shellfish are preferred to fillets, (b) flounder is the preferred fillet, (c) fillets are preferred because of ease of preparation, (d) smaller portion packages (1/2 pound) are desired, (e) a sauce should be included with the package, (f) a variety fish plate package including shrimp, scallops and fish sticks is desired, (g) the product flavor should be improved, (h) preparation methods should assure removal of all bones.

There are five major requirements for the optimum storage of fresh, refrigerated fishery products: (a) the temperature should be just above freezing to minimize bacterial and enzymatic activity, (b) the relative humidity should be high to prevent product dessication, (c) the atmosphere should be free of volatile compounds to prevent off-flavors, (d) minimization of bacterial contamination during processing and packaging, and (e) there must be proper packaging to maintain initial high quality.

All domestic and imported fresh fishery products are subjected to some form of packaging during distribution and marketing. Packaging plays an important role in providing

protection from physical damage. Quality standardization is needed for efficient production and marketing.

Heat-sealed plastic film pouches offer promise as attractive moisture-proof packages for fishery products. Evacuation of air from the pouches prior to sealing may promote the growth of anaerobic bacteria unless the product is of high initial quality and properly refrigerated during storage.

Spoilage, handling and type of package are important considerations in the packaging of refrigerated fishery products. A low temperature is the most important single factor in retarding spoilage. A temperature of $32^{\circ}F$ is required to maintain fresh fish of acceptable quality for as long as nine days from the time they are caught. The best method of insuring a low uniform temperature is to keep the fish well packed with liberal amounts of ice.

Next in importance to storage temperature is packaging. The proper package may extend the storage life by one or more days and may mean the difference between profit and loss. A new package, whether, 100, 20 or 1 pound in size, should be evaluated for: (a) quality maintenance, (b) efficient handling, (c) appearance, and (d) cost.

1. Clams Processing and Packaging

Four species of clams are taken commercially on the Atlantic Coast. These are the soft shell clam, the hard shell clam, the ocean quahog and the surf clam. The hard shell clam is the most important variety on the West Coast. Clams are brought ashore in the shell and are washed and graded into various sizes. The smallest legal size hard shell clam is called the little neck. Clams slightly larger than the little neck are called cherrystones. Larger clams are classed as medium and are used in canning. Hard shell clams are shipped in barrels and bags. Soft shelled clams are generally shipped in bushel baskets.

Clams are opened by inserting a knife between the two shells and the meat is then cut loose from between the shells. The washed clam meats are allowed to drain, are packed in gallon-size friction top metal cans and shipped to wholesalers in wooden boxes packed with finely crushed ice.

2. Crabmeat - Processing and Packaging

There are several species of crabs caught commercially in this country. The blue crab is the most important. It is caught on the Atlantic Coast from Massachusetts to Texas. It is most abundant in the Chesapeake Bay area and certain parts of the Gulf Coast. The next most important crab is the Dungeness

which is found along the West Coast. Alaska King Crab is found in the Bering Sea and the coastal waters of the Alaska Peninsula. Blue Crabs are marketed: (1) live (hard shelled), (2) cooked crabmeat, and (3) soft-shelled.

The meat of the Blue Crab is prepared by cooking in steam or boiling water and then removing the meat from the shell by hand. Claw meat which is darker in color is kept separate from the light colored body meat. During picking, the body meat is separated into grades as white flake, back fin lump, and mixed. These grades signify to a degree the size of the pieces of meat within a particular grade. The various grades of meat are generally packed in one-pound tin cans. The cans are packed in barrels with crushed ice when ready for shipment. Frozen crabmeat rapidly becomes spongy and fibrous in texture and loses flavor during storage.

The method of catching and preparing Dungeness Crab is similar to that used by the North Atlantic lobster fishery. Dungeness crabmeat is packed in waxed fibreboard cartons and metal cans of 1/2, 1 and 5 pound capacity. The five pound can is the most important commercially. Small quantities of Dungeness crabmeat are frozen but loss of texture and flavor limit the storage life to a relatively short period.

King Crabs are caught in tangle nets, otter trawl and large pots. King Crabs are butchered, cooked in boiling water for fifteen minutes, and quickly cooled in cold water. The picked meat is washed in a weak brine with rapid agitation to remove adhering material. King crabmeat is more suitable for freezing than the meat of other crab species. To minimize loss of texture and discoloration, the cooked crabmeat is generally packaged tightly in a moisture vapor-proof container.

3. Haddock and Flounder - Processing and Packaging

East Coast haddock and flounder are eviscerated or gutted at sea before being iced. When taken off the Pacific Coast these fish are iced in the round.

A fillet is a piece of boneless flesh cut away from the side of the fish along the backbone behind the pectoral fin to the tail section. Fresh fillets are generally marketed in one of three ways: (a) the skin of boneless flesh is left on, (b) the skin is removed, or (c) the fillets are left adhering together (butterfly) by the uncut skin of the belly.

Iced fillets may be wrapped in parchment paper or cellophane and then packed in twenty-pound slip covered metal cans. Five to twenty-pound waxed chipboard or fibreboard cartons with telescoping covers are also used. The fillets are rapidly cooled to $30^{\circ}F$ by

placing the containers in an air blast at 0° F. To maintain fish fillets at 32° F during shipment the containers are packed in crushed ice in large wooden boxes.

A small volume of fresh fish fillets is prepackaged at the retail market for sale in consumer-size units. The usual procedure is to pack them in a lightly-waxed cardboard tray and overwrap with cellophane, polyethylene or similar plastic film material. Recently some fillets and shellfish have been prepackaged in a polyester-polyethylene type pouch.

Plastic-coated, waxed-impregnated, moisture-resistant corrugated boxes have been developed for shipping fifty-pound lots of iced fillets, round or eviscerated fish. These fibre boxes are intended for single-use shipments. The corrugated fibre shipping box provides insulation and helps to reduce ice melting. Plastic boxes have also been tried as a replacement for the usual wood box. These containers are light, rugged and easy to clean. The primary requirement of the bulk package is to provide a satisfactory container for the wet refrigerated fishery products where the container must be durable, moisture resistant, resistant to fish odors and inexpensive to permit discarding after a single use. It must also have insulating qualities, compactness, and be easy to handle. Some fibreboard containers absorb up to 50% moisture and may loose up to 75% of their original strength.

4. <u>Shrimp - Processing and Packaging</u>

Methods of preparing shrimp vary in different areas. Most of the Alaskan shrimp are marketed in the frozen, cooked form, whereas the bulk of South Atlantic and Gulf shrimp are not cooked prior to marketing. The raw Gulf shrimp are beheaded, washed and inspected for defects, graded according to size and iced for distribution as fresh shrimp or packed for freezing. A small quantity of shrimp is peeled, deveined and then frozen. Size grading, peeling and deveining operations are done by machinery. Several sizes of cartons are used for packaging frozen shrimp. The 8, 10 and 12-ounce consumer size waxed cartons with overwrap and the one-pound tray type carton with overwrap are used. The larger bulk size cartons used are of 2-1/2, 5 or 10-lb capacity.

B. EXPERIMENTAL RADIATION PASTEURIZATION DATA FOR SELECTED REFRIGERATED FISHERY PRODUCTS

TABLE 10

EXPERIMENTAL RADIATION PASTEURIZATION DATA FOR SELECTED REFRIGERATED FISHERY PRODUCTS

Sea Food	Ref. No.	Invest-igator	Institution	Product Irradiated Name	Product Irradiated Region	Product Wt. Oz.	Pre-Treatment	Container Description: Material Type	Material Specific	Style	Coating	Size	Overwrap	Vacuum Closure	Radiation Source	Energy Level
CLAMS (shucked)	356	Steinberg	USDI	Soft Shell	New Eng.	-	None	Metal	Tinplate	Can	C-Enamel	307 x 409	None	25"	Spent fuel ele.	0.8 Mev.
	450	Brooke	USDI	Soft Shell	New Eng.	-	None	Metal	Tinplate	Can	-	307 x 409	None	No	Cobalt 60	1.2 Mev.
CRABMEAT (cooked)	207	Lerke	Un. of Calif.	Dungeness	Pacific	-	5% NaCl Dip	Plastic	Polyethylene-Polyester	Bag	None	Not given	None	No	Accelerator	5-6.5 Mev.
FLOUNDER (fillets)	207	Lerke	Un. of Calif.	Dover	Pacific	-	5% NaCl Dip	Plastic	Polyethylene	Bag	None	Not given	None	No	Accelerator	5-6.5 Mev.
	111	Eukel	Applied Rad.	Sole	Pacific	1" thick	None	Plastic	Polyethylene-Polyethylene-Polyester	Bag	None	Not given	None	No	Accelerator	8. Mev.
HADDOCK (fillets)	255	Nickerson	MIT	Large	New Eng.	3"x5"	Cold water wash	Plastic	Cellophane	Bag	None	3" x 5"	None	No	Accelerator	3 Mev.
	287	Proctor	MIT	Large	New Eng.	-	None	Plastic	Polyethylene	Bag	None	Not given	None	No	Accelerator	3 Mev.
	450	Brooke	USDI	Large	New Eng.	-	None	Metal	Tinplate	Can	-	307 x 409	None	No	Cobalt 60	1.2 Mev.
SHRIMP (cooked & peeled)	207	Lerke	Un. of Calif.	Pendalus	Pacific	-	5% NaCl Dip	Plastic	Polyethylene-Polyester	Bag	None	Not given	None	No	Accelerator	5-6.5 Mev.
	52	Brody	Whirlpool	Jumbo	Gulf	8	None	Plastic	Cellophane	Bag	Polyethylene	4" x 6"	#2 can	6"	Not given	Not given

Sea Food	Ref. No.	Dosage Range (Mrad.) Min.	Opt.	Max.	Storage Temp. °F.	Storage Life of Optimum Irradiated Product Relative to Organoleptic Rating (Days): Least Acceptable (No-Irr.)	Least Acceptable (Irr.)	Acceptable (Irradiated)	Most Accept. (Irradiated)	Initial Bacteria Content: Control	Opt. Irrad.	Microbial Sensitivity: Microorganism	Dose (Mrad)	Vol. Red. Substs. (μ equivs. red./5 ml.): Initial Control	Acceptable Irrad.	Container Changes Due to Irradiation: Remarks	Dose (Mrad)	General Comments
CLAMS (shucked)	356	.23	1.4	1.4	35	178 @ 0°F.	178	27	4	not given	not given	Not given	-	Not given	Not given	None	1.4	No significant differences between frozen control and 1.4 dose samples during storage. Level of storage temp. primary factor.
		.35	.45	.55	33			30	20									
CRABMEAT (cooked)	207	.05	.25	.25	35	4	12	8	6	8×10^5	1.5×10^4	Not given	-	5.6	4.1	None	0.25	Addition of 25 ppm CTC increases storage life to 27 days.
FLOUNDER (fillets)	207	.067	.27	.27	42	3	23	13	8	3.6×10^4	8×10^2	1. Pseudomonas 2. Achromobacter	0.10 0.40	5.2	4.7	Volatile material in bag	0.27	Addition of 5 ppm CTC increases storage life to 37 days.
	111 336	.25	.25	.25	42	4	24	19	15	not given	not given	Not given	-	5.0	7.0	None	0.25	
HADDOCK (fillets)	255 336	.40	.70	.70	38	10	42	28	21	4×10^5	60	Not given	-	0.13 (TMN)	1.6	None	0.7	
		(Double Pass)																
	287	1.5	-	1.5	33	8	-	-	15	1×10^5	0	Not given	-	0 (TMN)	11.0	None	1.5	Level of storage temp. primary factor.
		.05	.25	.35	33			30	21									
SHRIMP (cooked & Peeled)	207 52	.05	.25	.25	35	4	19	14	6	8×10^5	4×10^4	Not given	-	8.7	6.7	None	0.25	Addition of 25 ppm CTC increases storage life to 21 days.
		.09	.46	.46	35	16	110	-	-	3×10^6	3×10^2	Not given	-	Not given	Not given	None	0.46	Initial off flavor, loss of flavor & color; flavor threshold 0.23 M rad.

Additional Limited Radiation Pasteurization Dataon Refrigerated (35°F.) Product Storage Life

Sea Food	General Comments	Ref. No.	Invest-igator	Institution	Best Dosage (Mrad)	Max. Dose for Acceptance	Acceptable Quality (days)
CLAMS (shucked)	-	31	Carver	USDI	0.50	1.5	Not given
CRABMEAT (cooked)	Bitter flavor and stringy texture developed at 0.75 Mrad.	31	Bender	USDI	0.75	0.75	60
		235	Miyauchi	USDI	0.75	0.75	Not given
FLOUNDER (fillets)	Some off odors but taste and color unaffected at 0.5 Mrad.	235	Miyauchi	USDI (Seattle)	0.50	0.75	21
HADDOCK (fillets)	-	31	Bender	USDI	0.70		Not given
		235	Proctor	MIT	0.75	1.0	Not given
SHRIMP (cooked & peeled)	Some loss of flavor and color.	235	Miyauchi	USDI (Seattle)	0.25	0.25	Not given
		31	Bender	USDI (Maryland)	unacceptable	unacceptable	-

B. EXPERIMENTAL RADIATION PASTEURIZATION DATA FOR SELECTED REFRIGERATED FISHERY PRODUCTS

Marketing of fresh fishery products is a complex problem because many centers of consumption are located long distances from the production areas. Retention of product quality during processing, transit and distribution is an important economic factor.

A major interest of this survey is the combined process of radiation-pasteurization, packaging, and refrigerated storage to produce the maximum storage life of high quality fresh fishery products. Radiation processing techniques under development offer economical advantages meriting the additional expense required to commercialize a packaged, radiation-pasteurized fishery product. (see Table 10)

The potential annual market value is estimated at several hundred million dollars. Savings are possible through decreased: (a) product spoilage, (b) transportation costs, (c) storage costs, and (d) marketing costs.

Irradiation effects on fishery products have been studied using various sources of electron and gamma radiation. Electron sources used include the Van de Graaff electron accelerator, resonant transformer, and linear electron accelerator, while the gamma sources most employed have been radioactive cobalt-60 and spent fuel elements.

Most studies on the radiation preservation of fishery products have used high doses. Products receiving a dose of over three million rads are generally bacteriologically sterile. Certain pathogenic organisms are resistant to approximately four million rads, and destruction of enzymes requires a dose in excess of four million rads.

Relatively few studies have been carried out on the pasteurization of fishery products using radiation dose ranges between 100,000 and 500,000 rads; the data are sufficient, however, to indicate the general process and results that can be expected.

Radiation-pasteurization may be considered similar to the well-known milk pasteurization treatment in that the number of spoilage organisms is decreased and the storage life is increased. Extension of storage life, however, is negligible, unless the product is properly refrigerated. At the low dosage levels employed only minimum chemical and physical changes occur, and objectionable flavor, texture and color changes are generally small and insignificant. There is some bleaching of pigment in shrimp. Irradiation odors have been reported and are variable. Fatty fish such as mackerel and herring do not withstand pasteurization doses of irradiation, but low-fat fish such as haddock and flounder produce an acceptable product. Fresh fillets of some species may show changes in texture during storage due to enzymatic action, but this should not be a problem at recommended low storage temperatures.

Several methods of minimizing chemical and physical changes of the product during irradiation may be used, and at the pasteurization level

they may be useful in further reducing the radiation dosage required. These methods are: (a) irradiation in vacuum to minimize reactions with oxygen and (b) irradiation in the presence of acceptors to form harmless compounds.

Three major problems must be faced prior to the marketing of radiation-pasteurized fishery products in commercial channels: (a) Food and Drug Administration approval, (b) installation of proper equipment, and (c) consumer acceptance.

Radiation-pasteurization processing is considered a satisfactory technique for extending the shelf life of fresh fishery products when used in conjunction with proper packaging, refrigeration and marketing after irradiation. The use of radiation for this purpose, however, remains an experimental technique until it is proven safe, feasible and economical. Further studies on bacterial radio-sensitivity, flavor threshold levels and packaging requirements are required prior to commercial exploitation.

TABLE 11

ESTIMATED RADIATION PASTEURIZATION PROCESSING OF SELECTED REFRIGERATED FISHERY PRODUCTS

Sea Food	Present Refrigerated Storage Life (Days)		Desired Refrigerated Storage Life (Days)	Probable Irradiation Dose (Mrad)			Probable Refrigerated Storage Life After Irradiation (Days)		Possible Changes in Product Processing	Present Commercial Package	Possible Changes in Packaging Method
	Chill 32°F.	Retail 40°F.		Min.	Probable	Max.	Acceptable Quality (42°F)	Acceptable Quality (33°F)			
CLAMS (shucked)	14	3	28		0.45	0.55	20	30	None	Metal can	Vacuum Pack Flexible Bag Overwrapped Trays
CRABMEAT (cooked)	7	2	21	0.2	0.4	0.5	12	21	1. 5% Brine Dip 2. Addition of Antibiotic	Metal can	Vacuum Pack Flexible Bag Overwrapped Tray
FLOUNDER (fillets)	7	3	21	0.15	0.25	0.5	19	30	None	Metal can Waxed cartons	Vacuum Pack Flexible Bag Overwrapped Tray Overwrapped Carton
HADDOCK (fillets)	10	3	28	0.15	0.25	0.5	21	30	None	Metal can Waxed carton	Vacuum Pack Flexible Bag Overwrapped Tray Overwrapped Carton
SHRIMP (cooked & peeled)	7	3	21	0.1	0.25	0.5	14	19	1. 5% Brine Dip 2. Addition of Antibiotic	Metal can Waxed carton Wood box	Vacuum Pack Flexible Bag Overwrapped Tray

C. ESTIMATED RADIATION PROCESSING OF SELECTED REFRIGERATED FISHERY PRODUCTS

Radiation Dose and Storage Temperature

Table 11 indicates the probable radiation dose that may be used for pasteurizing fishery products and the probable refrigerated storage life after radiation without product injury and with inhibition of bacterial spoilage.

Maintaining the storage temperature as near to 33°F as possible during the entire processing and distribution cycle plays a significant role in the acceptability of the fishery products.

Short summaries of the radiation requirements follow:

1. Clams (shucked)

Irradiation of clams in a range between 230,000 and 1,400,000 rads prevented bacterial spoilage without product deterioration for 119 days at 35°F. Doses required for complete destruction of spoilage bacteria resulted in loss of product flavor and texture. A 450,000 rad dosage is considered optimum for bacterial control, minimum radiation injury, acceptability, and shelf life extension. (31,356, 450)

2. Crabmeat (cooked)

Irradiation of crabmeat in a range between 250,000 and 750,000 rads prevented bacterial spoilage without product deterioration for 60 days at 35°F. The controls showed bacterial spoilage after four days at 35°F. Doses required to destroy spoilage bacteria completely resulted in bitter flavor.

and stringy texture. A 400,000 rad dosage is considered optimum for bacterial control and minimum radiation injury. (31,207,235)

3. Flounder (fillets)

Irradiation of flounder fillets in a range between 250,000 and 750,000 rads prevented bacterial spoilage without product deterioration for 30 days at 35°F. The controls showed bacterial spoilage after four days at 35°F. Doses required to destroy the spoilage bacteria resulted in off-odors. A 500,000 rad dosage is considered optimum for bacterial control and minimum radiation injury. (111, 207, 235, 336)

4. Haddock (fillets)

Irradiation of haddock fillets in the range between 400,000 and 1,000,000 rads prevented bacterial spoilage without product injury for 42 days at 35°F. The controls showed bacterial spoilage after ten days at 38°F. Doses required to destroy the spoilage bacteria completely resulted in loss of product flavor and texture. A 250,000 rad dosage is considered optimum for bacterial control and minimum radiation injury. (31, 235, 255, 287, 336, 450)

5. Shrimp (cooked)

Irradiation of shrimp in a range between 100,000 and 500,000 rads prevented bacterial spoilage without product injury for 19 days at 35°F. The controls showed bacterial spoilage after four days at 35°F. Doses required to destroy spoilage bacteria completely resulted in loss of product flavor and color. A 250,000 rad dosage is considered optimum for bacterial control and minimum radiation injury. (31, 52, 207, 235)

D. A GUIDE TO THE APPLICABILITY OF FOOD PACKAGE TYPES TO THE SELECTED RADIATION PASTEURIZED FISHERY PRODUCTS

TABLE 12

A GUIDE TO THE APPLICABILITY OF FOOD PACKAGE TYPES FOR SELECTED RADIATION PASTEURIZED FISH

CLAMS(shucked); CRABMEAT(cooked); SHRIMP(cooked)

	Packaging Requirements					
	Provide Low O_2 Trans.	Minimal Off-Odors, Off-Flavors	Unaffected by Ice and Salt Water	Resist Rough Handling	Permit Efficient Irradiation	Package Material Extractives
1. Small Rigid Sealed Containers for Consumer End Use (Cans, Jars)						
Inside and Outside Enameled Steel Plate		4	1		b	2
Inside and Outside Enameled Tinplate		4			b	3
Inside and Outside Enameled Aluminum Plate		4			b	2
Composites with Metal Ends(Paper, Plastic & Al. Foil)	a	4	5	6	b	2
Glass*				7	b	
2. Large Rigid Sealed Containers for Bulk Use (Drums, Pails, Cans)						
Inside and Outside Enameled Steel Plate		4	1		b	2
Inside and Outside Enameled Tinplate		4			b	3
Inside and Outside Enameled Aluminum Plate		4			b	2
Composites with Metal Ends (Paper, Plastic & Al. Foil)	a	4	5	6	b	2
3. Semi-Rigid Packages Sealed and/or Overwrapped for Consumer End Use (Cartons, Trays, Tubs)						
Inside and Outside Enameled Aluminum Plate	a	8		6	c	3
Overwrap Coated Paperboard	a	8	5	6	c	3
Thermoformed Plastic	a	8		6	c	3
Composites with Metal Ends (Paper, Plastic & Al. Foil)	a	8	5	6	c	3
Laminates (Paper, Plastic & Al. Foil)	a	8	5	6	c	3
4. Flexible Packages for Consumer End Use (Bags, Pouches and Tetrahedron)						
Laminates (Paper, Plastic & Al. Foil)	a	8	5	6	f	3

FLOUNDER(fillets); HADDOCK(fillets)

	Packaging Requirements					
	Provide Low O_2 Trans.	Minimal Off-Odors, Off-Flavors	Unaffected by Ice and Salt Water	Resist Rough Handling	Permit Efficient Irradiation	Package Material Extractives
1. Small Rigid Sealed Containers for Consumer End Use (Cans, Jars)						
Inside and Outside Enameled Steel Plate		4	1		d	2
Inside and Outside Enameled Tinplate		4			d	3
Inside and Outside Aluminum Plate		4			d	2
Composites with Metal Ends (Paper, Plastic & Al. Foil)	a	4	5	6	d	2
Glass*				7	e	
2. Large Rigid Sealed Containers for Bulk Use (Drums, Pails, Cans)						
Inside and Outside Enameled Steel Plate		4	1		d	2
Inside and Outside Tinplate		4			d	3
Inside and Outside Aluminum Plate		4			d	2
Composites with Metal Ends (Paper, Plastic & Al. Foil)	a	4	5	6	d	2
3. Semi-Rigid Packages Sealed and/or Overwrapped for Consumer End Use (Cartons, Trays, Tubs)						
Inside and Outside Enameled Aluminum Plate	a	8		6	c	3
Overwrap Coated Paperboard	a	8	5	6	c	3
Thermoformed Plastic	a	8		6	c	3
Composites with Metal Ends (Paper, Plastic & Al. Foil)	a	8	5	6	c	3
Laminates (Paper, Plastic & Al. Foil)	a	8	5	6	c	3
4. Flexible Packages for Consumer End Use (Bags, Pouches and Tetrahedron)						
Laminates (Paper, Plastic & Al. Foil)	a	8	5	6	f	3

Note: The package types listed above should perform satisfactorily with only minimum additional evaluation with the exceptions of the problem areas indicated.

Package Design Comments

a. Suitable for air pack but vacuum pack questionable.
b. Either cylindrical or rectangular shapes could be adapted for use with this product.
c. Rectangular shape easily fabricated and should provide efficient use of radiation source.
d. Shape of product necessitates rectangular shape package.
e. Package not applicable because of shape of product.
f. Tetrahedron shape may not be efficient, rectangular shape may be preferred.

* MATERIAL DISCOLORS WHEN IRRADIATED.

Package Material Comments

1. More susceptible to corrosion than other metal container materials.
2. No extractives data available.
3. Limited extractives studies conducted.
4. Definitive organoleptic evaluation has not been reported, however, inside enamel specification should follow present practice for similar fish products.
5. Structure is liable to surface puncture and water absorption.
6. Susceptible to damage.
7. Susceptible to breakage.
8. Material selection for these types will have a high probability of organoleptic contribution to food product and must be chosen carefully.

D. A GUIDE TO THE APPLICABILITY OF FOOD PACKAGE TYPES TO THE SELECTED RADIATION PASTEURIZED FISHERY PRODUCTS

In Table 12, the container requirements are compared with package types which have achieved high volume usage in packaging foods similar in packaging requirements to the food products selected for study in the AEC program. The estimates of performance for the package types reflect the information reviewed in Part I, the previous sections of Part II, and the past experience of Continental Can Company in furnishing packages to the food processing industry. In most package type categories a variety of specific materials are available which will likely perform adequately.

Definitive material costs and non-technical aspects of food packaging are not within the scope of this study.

Some new packaging concepts may be required to package refrigerated, radiation-pasteurized fishery products. It appears that the packaging employed will be similar to types presently used.

The characteristics of a satisfactory package for refrigerated radio-pasteurized fishery products are:

(1) low oxygen transmission.

(2) grease-proofness.

(3) good thermal conductivity.

(4) minimization of off-flavor, off-odor, and color loss from the package.

(5) impermeability to moisture.

(6) unaffected by ice and salt water.

(7) ability to withstand refrigerated temperatures.

(8) resistance to rough handling.

(9) good vacuum retention.

(10) leakproof construction.

(11) easy filling and sealing.

(12) a design that permits efficient irradiation.

The following general classes of packages are envisioned for radiation-pasteurized fishery products.

(1) Large rigid packages sealed for bulk end use.

(2) Small rigid packages sealed for consumer end use.

(3) Semi-rigid packages sealed and/or overwrapped for consumer end use.

(4) Flexible packages for consumer end use.

Three sizes of packages are envisioned for radiation-pasteurized fishery products. These are:

(1) A 10 to 16 ounce consumer size package.

(2) A 5 to 10 pound institutional or bulk style package.

(3) A 10, 20, 30, or 50 pound large rigid package for bulk use.

At pasteurization doses of 500,000 rads or less the changes in the physical and chemical properties of the packaging materials are very slight. Gaseous products may be released from some materials and contribute to off-flavors and odors. Proper selection and modification

of packaging materials can minimize this problem.

The major problem of vacuum packaged refrigerated radiation-pasteurized fishery products is one of possible anaerobic bacterial spoilage when low oxygen contents are required. Proper sanitation, refrigeration and high initial quality of fish must be maintained to avoid anaerobic spoilage. Plastic film structures can be fabricated into packages. or metal containers used, to maintain a low oxygen atmosphere. Packages also must permit storage of the fishery products for several weeks at refrigerated temperatures and possibly in salted ice water, followed by extended transport, before marketing.

Investigation of bacterial penetration in flexible packaging materials showed that no penetration was found in plain flat plastic sheets or heat sealed bags with gauges of 0.5 mil or more. Plain aluminum foils showed varying degrees of penetration. Creasing of plastic films increased the chance of bacterial penetration, but heating or irradiation did not.

Flexible containers must be capable of resisting the rough handling encountered in shipment. The ability of this type package to resist abuse depends upon the design and construction of the folding carton and shipping container, as well as the primary package. The design of the shipping container has a bearing on the irradiation equipment since it may be desirable to irradiate the sealed shipping container and minimize packaging and handling operations after irradiation. A shipping container rugged enough to withstand rough handling may be too dense for irradiation; and

one acceptable from an irradiation standpoint may be too weak to withstand rough handling. The indications are that packages, either rigid, semi-rigid, or flexible should be assembled in small units for irradiation and three or four units assembled in the final shipping container after irradiation.

Package design for radiation-pasteurized fishery products requires consideration of the food shape. While a cylindrical container may be used for items such as crabmeat, clam meat and shrimp, a rectangular package is better suited for flounder and haddock fillets. The rectangular package also permits compactness for greater efficiency during irradiation. From an economic point of view the flexible plastic package has weight and volume advantages.

E. Conclusions

1. Presently known package engineering can provide most of the functional requirements for radiation-pasteurized fishery products.

2. Possible organoleptic contributions from the food package to the fishery products will require further study, since definitive data are not available at the estimated radiation dose level of approximately 500,000 rads.

3. The use of refrigerated temperatures during storage of radiation-pasteurized fishery products should tend to minimize chemical interaction between the package and the food, thus mitigating some of the undesirable characteristics of packaging materials

which were irradiated and stored at room and elevated temperatures.

4. Exact dimensions of the three general classes of packages can not be specified, nor the most economical radiation source configurations detailed, until further research on the food-technology aspects of radiation-pasteurized fish have been evaluated. Specifically, permissible dose variations in individual food containers must be established.

TABLE 13

PRESENT PRACTICES IN THE MARKETING OF THE SELECTED REFRIGERATED FRUIT PRODUCTS

Fruit	Ref. No.	1960 FRESH DOMESTIC MARKET: Annual Production (10^6#/yr.)	Fresh Market (10^6#/yr.)	Fresh Producing State	% Fresh Fruit Produced	Farm Value (Value	Processor Value 10^6\$/yr.)	% of Fresh Crop Prepackaged	Geographical Distribution Sales % of Total Market: Eastern	Central	Western	CONSUMER PACKAGE AND MASTER CONTAINERS: Material Type	Material Specific	Style	Overwrap	Size	Master Container	Size
GRAPES	433	6,052	1,056	Calif.	95	203.5	162.5	5	-	-	-	Plastic	Cellophane	Bag	None	1 lb.	Wood lug	28 lb.
	346 407			Mich.	1							Paper	Fibreboard	Basket	None	4-12 qt.	-	-
	145			N. Y.	1							Paper	Fibreboard	Box	None	20 lb	-	-
GRAPEFRUIT	407	3,444	1,836	Fla.	83	63.2	91.8	19	56	16	26	Plastic	Polyethylene	Bag	None	5,8 lb.;6 count	Wood or FB Box	30,50,60 lb.
	346			Tex.	10							Textile	Cotton	Mesh Bag	None	5,6,8 lb.	Wood or FB Box	30,50,60 lb.
				Calif.	6							Wood	Pine	Box	None	80 lb.	-	-
LEMONS	407	1,370	702	Calif.	99	35.8	61.4	19	-	-	-	Plastic	1. PE	Bag	None	1,2 lb.	FB Box	38 lb.
	346												2. RHC	Bag		3,6,12 count	FB Box	38 lb.
												Paper	Kraft	Tray	Cellophane	4 count	FB Box	38 lb.
ORANGES	407	11,108	4,485	Fla.	66	415.4	299	19	62	18	20	Plastic	1. PE	Bag	None	4,5,8,10 lb.	Wood Box	90 lb.
	346			Calif.	31								2. RHC	Bag		4,5,lb.	FB Box	37 lb.
				Tex.	2							Textile	Cotton	Mesh Bag	None	5,8 lb.	FB Box	37 lb.
PEACHES	349	3,412	1,702	Calif.	45	132.2	64.1	7	-	-	-	Wood	Veneer	Basket	None	1/2,3/4, & 1 bu.		
	407			S. Car.	7							Wood	Pine	Box	None	16-18 lb.		
	156			Ga.	6							Paper	Fruit tissue	Overwrap	None	-	Box	22-23 lb.
				Mich.	5													
				Pa.	4													
STRAWBERRIES	407	534	266	Calif.	40	85.1	53.2	100	-	-	-	Wood	Veneer	Basket	None	1/2,1 pt.,1 qt.	Wood Crate	
	242			Ore.	13							Plastic	Polystyrene	Basket	None	1 pt.		
	156			Wash.	8							Paper	1. FB	Basket		1 pt.;1 qt.		
				Mich.	8								2. Pulp	Basket	None	1 pt.; 1qt.		
				Tenn.	6													
				Ark.	4													
TANGERINES	407	405	261	Fla.	100	10.8	17.4	19	-	-	-	Plastic	1. PE	Bag	None	4,5,8,10 lb.	Wood Box	30,50,60,90 lb.
													2. RHC	Bag		4,5 lb.	FB Box	40,50 lb.
												Textile	Cotton	Mesh Bag	None	5,8, lb.	FB Box	40,50 lb.
TOMATOES	417	10,457	1,882	Calif.	33	225.1	143.1	65	54	10	36	Plastic	Polystyrene	Tray	Polystyrene	10 to 16 oz.	FB Box	32,40,50 lb.
	110 355			Fla.	20							Paper	Kraftboard	Basket	None	8,12,16 qt.		-
	350 407			Tex.	9							Paper	Kraftboard	Tray	Cellophane	10 to 16 oz.	FB Box	32,40,50 lb.
	346 151			Mich.	4							Wood	Veneer	Basket	None	3,12 qt.;1/2,1bu.		
	12 351			N. J.	4							Wood	Pine	Lug	None	32,40,50 lb.		

Fruit	Ref. No.	Freezing Pt.	CHILL STORAGE LIFE: Opt. Temp. °F.	RH. %	Days	Retail Storage Temp. °F.	Retail Storage Life (Days)	Respiration Rate (mg./kg./hr.) 32°	40°	70°	% Weight Loss: Perforated Package	Not Packaged	Type of Spoilage	Percent Spoilage: Repack	Transit	Retail	Dollar Loss Spoilage (10^6\$/yr.)
GRAPES	355	(AM.)27.5	31-32	80-85	21-56	43	1-3	-	-	-	-	-	Black Mold	-	-	10	16.2
	183	(Eur.)24.8	30-31	85-90	90-180								Alternaria Rot				
	164												Cladosporium Rot				
	210												Gray Mold				
	221												Rhizopus Rot				
GRAPEFRUIT	175	28.4	32	85-90	28	40	4-5	-	-	-	-	-	Green Mold	8	-	12.8	5
	243 355												Blue Mold				
	221 183												Stem End Rot				
LEMONS	355	28	55-58	85-90	30-90	70	8-10	-	-	-	-	-	Green Mold	-	-	7.8	2.5
	183												Blue Mold				
	165 210												Alternaria Rot				
	221 212												Brown Rot				
ORANGES	175	28	30-34	85-90	56-84	40	4-5	2	4	35	-	-	Blue Mold	13	-	15.3	24
	208 355												Green Mold				
	221 183												Stem End Rot				
PEACHES	32	29.4	31-32	80-85	10-21	44	2-3	5	8	72	0.4	4.6	Brown Rot	-	-	5.8	6
	355												Rhizopus Rot				
	183												Green Mold				
	221 210												Gray Mold				
STRAWBERRIES	355	30.2	31-32	85-90	7	40	1-2	15	27	149	-	-	Gray Mold	-	20-30	25	10-15
	183												Rhizopus Rot				
	221 12												Sclerotinia Rot				
TANGERINES	355	28	31-38	90-95	14-28	42	3-4	3	5	40	-	-	Blue Mold	-	-	10	10
	183												Green Mold				
	213 446												Stem End Rot				
TOMATOES	175	(Mature Green)	55-70	80-85	21-35	70	2-3	5	10	80	-	-	Green Mold	12	3	2-9	25
	355	30											Alternaria Rot				
	183	(Ripe)											Soft Rot				
	221	30	40-50	80-85	7-10	40							Rhizopus Rot				

E. PRESENT PRACTICES IN THE MARKETING OF THE SELECTED REFRIGERATED FRUITS

The fruits of major interest in this survey of packaging requirements for refrigerated radiation-pasteurized foods are grapes, peaches, strawberries, tomatoes, and the citrus fruits -- oranges, grapefruit, lemons and tangerines.

Table 13 lists the 1960 annual production dollar value, producing state, and geographical sales of the eight selected fruit products.

1. Spoilage

Food spoilage may be defined as any unacceptable change in flavor, appearance, texture or nutritive properties. Various factors cause spoilage of fresh fruits:

a. Microorganisms such as mold, yeast and bacteria.

b. Chemical reactions such as oxidation which result in off-flavors.

c. Enzymatic reactions which cause discoloration.

d. Physical damage from rough handling or insect penetration which then leads to fungi spoilage.

e. Improper storage temperature and humidity.

f. Improper packaging.

Acceleration of the life process and the growth of spoilage fungi are the major causes of deterioration of fruit. The United States Department of Agriculture has

estimated the loss of fruit in the United States during marketing at 11% or $249,000,000 a year.

2. Preparation for packaging

The processing steps followed when preparing fresh fruit products for shipment vary with the commodity, the retail market and the consumer. The processing steps generally performed at the packing plant are unloading, weighing, cleaning, sorting, grading, packing and reloading. Additional processing steps that may be employed to improve the storage life of the product are:

a. Washing--borax-treated water to control growth of spoilage fungi on citrus products.

b. Prepackaging--to minimize recontamination and secondary spoilage.

c. Refrigeration--to inhibit mold decay and decrease product respiration rate.

d. Application of chemical inhibitors--paper wraps treated with diphenyl and copper compounds to control mold decay on citrus products.

e. Fumigation--sulphur dioxide for controlling mold on grapes.

f. Coating--waxing oranges to control fungi and moisture loss.

3. Packaging

Fresh fruit may be packaged in trays, cartons, cups, boxes, baskets, drums, pails, or bags. A number of different types of containers have been developed for specific uses. Table 13 lists some of the major commercial types. Machines have been developed for setting up, filling, overwrapping and sealing containers.

The major requirement of a package is to insure complete protection of the contents. The selection of the proper material for each product packed is therefore essential.

The packer considers a number of factors when selecting a material and the design of a container. Generally, a package is selected that most economically meets basic requirements of protection, preservation, convenience and appeal. Usually the important factors are technical. The materials must be organoleptically acceptable and non-toxic when used to package the product. Consideration also must be given to moisture loss, grease proofness, tensile strength, gas permeability, transparency, light transmission, chemical inertness, and printability.

a. Odor

Foreign odors may be imparted to the contents of a package in several different ways. The packaging material

may have an odor which is transmitted to the contents. A chemical action may occur between the contents and the packaging material to alter the normal odor. Most food packaging materials do not present these problems. The problem of odors in packaging is usually one of transmission through loss of product aroma or external contamination. Odor transmission may result from a lack of material resistance to some special property of the contents. Essential oils may penetrate the packaging material. External chemicals may alter the odor when the contents are insufficiently protected.

b. Bacterial and Insect Attack

Microorganisms may cause damage to packaging materials. Paper, cellophane, cardboard, wood, some plastics, and fabrics are subject to attack by microorganisms.

Insects may cause damage to packaging materials. They may attack the packaging material to reach the contents, feed on the packaging material itself or the animal or vegetable type adhesive. Textile bags offer the least protection against insects. Paper packages offer limited resistance to some penetrating species. Plastic films are an effective barrier against non-penetrating insects. Polyethylene is more resistant to penetration than cellophane. Resistance depends

upon material, thickness, and lamination to other materials. Laminated aluminum foil offers improved protection against insects, but is not insect proof. Some insects are capable of penetrating 50-pound kraft, laminated aluminum foil or laminated asphalt paper. Fibreboard is the most resistant to insect penetration of any of the packaging materials mentioned. If poorly constructed the fibreboard container usually offers little protection against insect invasion at the seams.

c. Mechanical Damage

An important function of a fruit package is the prevention of product damage which hastens tissue deterioration. Post harvest handling subjects fresh fruits to a variety of vibrations and impacts. Two important types of product injury are surface abrasion and impact bruises. Abrasion results from fruit rubbing against the container, conveyor belts or each other. Vibrations are transmitted to the package product during transit. Impact bruises occur during or after harvest when fruit is dropped, or subjected to severe transit impacts. One method of minimizing transit injury is to pack the fruit tightly within the container to prevent movement. Cold fruits are less subject to vibration injuries. Warm fruits are less subject to impact bruises.

d. Thermal Conductance of Packages

Some fruits are packaged prior to cooling. The thermo-conductivity of the package then must be considered. The cooling method may determine the packaging material. Packaged fruits hydro-cooled with water requires that the packaging material must withstand soaking. Ventilation of the container is necessary to increase the rate of heat removal.

e. Permeability

Fresh fruits require a packaging material that should be relatively impermeable to water vapor and moderately permeable to oxygen and carbon dioxide. The atmosphere developed within the package of fruit depends upon the temperature, the permeability of the material and the construction of the package. In general, an oxygen level of approximately 2 to 5% and a carbon dioxide level of 15 to 20% will decrease the respiration rate and increase the storage life of the refrigerated product. Each variety behaves in a different manner and proper modified atmospheres must be determined. Respiration depletes the oxygen and increases the carbon dioxide level within the package. Oxygen consumption and carbon dioxide production are balanced by the permeation of these gases through the packaging material.

Table 13 compares respiration rates of several fruits when held at various temperatures.

f. Plastic Materials

A number of plastic materials is available which offer physical and chemical properties required for proper packaging. Three types of plastic containers, rigid, semi-rigid and flexible are made. They may be made of two types of materials, thermoplastics, such as polyethylene and thermosetting plastics, such as ureas, and phenolics.

Polystyrene is used in the manufacture of rigid containers. Semi-rigid containers are made from polyethylene or cellulosic thermoplastics by injection molding, filming, or drawing. Flexible containers or plastic film bags are made from many different plastics.

g. Paper Materials

Paper containers are made from various materials in a wide variety of sizes and forms. Some are resistant to cold, heat, acid or alkaline materials. Paper food containers are divided into two classes, namely, light duty and heavy duty. Light duty containers are usually made of three pieces, a body, a bottom, and a cover. Other light duty containers may be made of one piece such as the folding carton. Heavy

duty containers may be made with heavy bodies with a single or double wrap.

Significant changes have been made in the use of fibreboard shipping containers in place of baskets, hampers and nailed wooden containers. A general reduction in size of shipping container has occurred with the development of automatic filling and consumer unit packaging. Oranges, grapefruit and lemons, are now packaged extensively in fibreboard containers. Eastern peaches are packed in fibreboard boxes instead of bushel baskets. Fibreboard boxes having one-half the volume of the old standard nailed wooden box have been adopted in California and Arizona as standard shipping containers for bulk oranges, lemons and grapefruit.

h. Plastic Liners and Mesh

The use of plastic film liners inside shipping containers has had a notable effect on the marketing of some fresh fruits. These large bags were originally developed for pears. The film modifies the atmosphere to retard respiration and prolong the storage life. Film liners are of value for reducing deterioration due to loss of moisture.

A few commodities, such as oranges, are packed in large consumer units using textile or plastic mesh. Textile

mesh bags have been used for many years, have the advantage of low cost and have a reasonable tensile strength. The disadvantages are that they cannot be made waterproof, and are subject to attack by fungi and insects.

4. Prepackaging

In 1954, approximately 20% of the fresh fruits and vegetables marketed were prepackaged before delivery to retail stores. By 1958, prepackaging had increased to 32%. Additional prepackaging is done at the retail level with a 1960 total now estimated at approximately 55%. The extent of prepackaging varies considerably for the different products. Some are not adapted to prepackaging. Approximately 100% of the strawberry crop marketed fresh is now prepackaged. It is estimated that 65% of the tomatoes and 19% of all citrus products are now prepackaged. Table 13 lists the estimated % of prepackaged fruits.

Fresh fruit may be packaged in consumer units at the shipping point, the terminal market, wholesale market, or the retail store, depending on the commodity and requirements. Marketing fresh fruits in a prepackaged consumer unit is rapidly displacing the large box bulk method. Large scale prepackaging of fresh fruit and vegetables began in retail stores.

TABLE 14

EXPERIMENTAL PACKAGING DATA

Fruit	Ref. No.	Invest-igator	Institution	Product Source Region	Product Source Name	Product Wt. Oz.	Pre-Treatment	CONTAINER DESCRIPTION Material Type	Material Specific	Shipping Container	Style	Size	Storage Temp. °F.	Relative Humidity
GRAPES	443									None	Bag	5"x3-1/2"x14"	40-70	Not given
	155													
	167	Havis	U.S.DA.	Calif.	Not given	24	None	Plastic	Polyethylene					
GRAPEFRUIT	161													
LEMONS														
ORANGES	167	Havis	U.S.D.A.	Calif.	Not given	80	None	Plastic	Polyethylene	None	Bag	6"x3-1/2"x15"	40-70	Not given
	189	Kaufman	U.S.D.A.	Fla.	Pineapple	40	Calif.	Plastic	Polyethylene	Wire Bound Crates	Bag	6"x3"x17" (5#)	70	58-92
					Valencia		Diphenyl Pads			Fibreboard Boxes	Bag	10"x15" (5#)	70	50-80
				Calif.	Valencia			Cloth	Cotton					
					Navel									
	180	H. Ruschka	U.S.D.A.	Fla.										
PEACHES	155													
STRAWBERRIES	8 155													
TANGERINES														
TOMATOES	24													

Fruit	Ref. No.	Container Style	Type of Wrap	Weight Loss % 70°F. 4 (Days)	Weight Loss % 70°F. 7 (Days)	Weight Loss % 40°F. 4 (Days)	Weight Loss % 40°F. 7 (Days)	Total Decay % 70°F. 4 (Days)	Total Decay % 70°F. 7 (Days)	Total Decay % 40°F. 4 (Days)	Total Decay % 40°F. 7 (Days)	Storage Life of Product Relative to Organoleptic Rating (Days) Least Acceptable	Acceptable	Best Quality	Initial Microbial Content Control	Initial Microbial Content Opt. Irrad.	General Comments
GRAPES	167	Open Tray	None	9.4	14.3	4.6	5.8	7.0	5.0	4.4	5.8	7	4	4	-	-	
		PE Bag	None	4.5	8.3	2.1	3.6	2.6	14.2	1.4	4.8						
GRAPEFRUIT																	
LEMONS																	
ORANGES	189	PE Bag	-	1.5		-		12-14		-		7	-	-	-	-	Perforated-8-64 1/4" holes
		Mesh Bag	-	5.1		-		7.3	11.5	-		7	-	-	-	-	Pencillium rot-stem end rot
	167	PE Bag	None	0.7	1.1	0.5	0.8	2.8	1.4	0.0	0.0	7	7	4	-	-	
PEACHES																	
STRAWBERRIES	8																
TANGERINES																	
TOMATOES	24																

Specialized prepackaging firms located in terminal markets now serve the retailers. Prepackaging is rapidly expanding in the producing areas. Lower labor costs and the efficiency that results from large scale operations favor packaging at the growing or shipping point. The factors which have influenced the trend toward the smaller consumer unit containers are:

a. Development of self-service markets.

b. Increase in operating efficiency.

c. Impulse buying and appeal of the package.

d. Increased demand for convenience.

e. Reduction of spoilage and waste.

f. Decreased transportation costs.

g. Development of lower cost packaging materials.

h. Development of new, improved packages.

Table 14 presents data on experimental packaging of fruits.

TABLE 15

EXPERIMENTAL RADIATION PASTEURIZATION DATA OF THE SELECTED REFRIGERATED FRUIT PRODUCTS

Fruit	Ref. No.	Investigator	Institution	Product Irradiated Name	Product Irradiated Region	Product Wt. Oz.	Pre-Treatment	Container Description: Material Type	Material Specific	Style	Coating	Size	Overwrap	Vacuum Closure	Radiation Source	Energy Level
GRAPES	37	Beraha	USDA	Tokay	Calif.	6	B. cinerea inoculate	Plastic	Polyethylene	Perforated Bag	None	3" x 5"	#2 can	None	Spent Fuel	0.8 Mev.
LEMON	34 35	Beraha	USDA	Not given	Calif.	3	None	Plastic	Polyethylene	Perforated Bag	None	3" x 5"	#2 can	None	Spent Fuel	0.8 Mev.
ORANGES	34 35	Beraha	USDA	Navel	Calif.	1-1/2	None	Plastic	Polyethylene	Perforated Bag	None	3" x 5"	#2 can	None	Spent Fuel	0.8 Mev.
PEACHES	32 316 246 35	Beraha Salunkhe McBrian	USDA Utah State Western RR	Elberta Elberta Elberta	Mich. Colo. Colo.	4 N.G. 2	2500 ppm.Cl. wash None None	Plastic Metal Paper	Polyethylene Tinplate Kraft	Perforated Bag Perforated Can Bag	None None None	4" x 5" 603 x 700 #10	#2 can None #10 can	None Aerated None	Spent Fuel Spent Fuel Spent Fuel	0.8 Mev. 0.8 Mev. 0.8 Mev.
STRAWBERRIES	37 316, 317 247	Beraha Salunkhe McBrian	USDA Utah State Western RR	N.G. Lindalicious Shasta	Ill. Colo. Colo.	4 N.G. N.G.	None 0.25% Sorbic None	Plastic Metal Paper	Polyethylene Tinplate Kraft	Perforated Bag Perforated Can Bag	None None None	3" x 5" 603 x 700 #10	#2 can None #10 can	None Aerated None	Spent Fuel Spent Fuel Spent Fuel	0.8 Mev. 0.8 Mev. 0.8 Mev.
TOMATOES	316, 317 35	Salunkhe	Utah State	Pink	Colo.	N.G.	None	Paper	Kraft	Bag	None	#10	#10 can	Aerated	Spent Fuel	0.8 Mev.

Fruit	Ref. No.	Dosage Range (M rad.) Min.	Opt.	Max.	Storage Temp. °F.	Storage Life of Optimum Irradiated Product Relative to Organoleptic Rating (Days): Least Acceptable (No-Irr.)	Least Acceptable (Irr.)	Acceptable (Irradiated)	Most Acceptable (Irradiated)	Initial Microbial Content: Control	Opt. Irrad.	Microbial Sensitivity: Microorganism	Dose	Container Changes Due to Irradiation: Remarks	Dose	General Comments
GRAPES	37	0.05	0.5	1.0	75	4	10	10	10	Not given	Not given	B. cinerea	1.0-2.0	None	1.0	Fermented odor at 1.0 M rad.
LEMONS	34	0.10	0.20	2.0	75	3	12 (17@55°F.)	5	5	Not given	Not given	P. digitatum P. italicum	0.5-1.0 0.5-1.0	None	2.0	Loss texture at 0.5 M rad. Skin discoloration at 0.5 M rad.
ORANGES	34	0.10	0.20	1.0	75	4 (15@41°F.)	20+ (65@41°F.)	20	Not given	Not given	Not given	P. digitatum P. italicum	0.5-1.0 0.5-1.0	None	1.0	Loss texture at 0.5 M rad. Skin discoloration at 0.5 M rad.
PEACHES	32	0.20	0.25	0.40	80	3	10+	10	Not given	Not given	Not given	Rhizopus Monilinia	0.5-1.0 0.25	None	0.4	No comments
	316	0.10	0.10	0.50	70	10	10	10	Not given	Not given	Not given	Not given	-	None	0.50	Softening of texture and browning of skin at 0.4 M rad.
	246	0.20	0.25	0.35	70	-10	30	20-30	20	Not given	Not given	Not given	-	None	0.35	Flavor threshold at 0.25 M rad. Acetic acid dip increases storage life.
STRAWBERRIES	37	0.10	0.20	1.0	41-75	2	8	7	7	Not given	Not given	R. stolonifer	0.5-1.0	None	1.0	Texture and color loss at 1.0 M rad.
	316, 317	0.10	0.30	0.40	40	10	45	45	Not given	Not given	Not given	Not given	-	None	0.40	Decrease in flavor and firmness at 0.40 M rad.
	247	0.20	0.20	0.35	37	2	40+	30	20	Not given	Not given	Not given	-	None	0.35	Paper outperforms rubber hydrochloride
TOMATOES	316, 317	0.10	0.30	0.40	70	10	39	17	Not given	Not given	Not given	Not given	-	None	0.40	Loss flavor and texture at 0.40 M rad.

Additional Limited Radiation Pasteurization Data on Refrigerated (35°F.) Product Storage Life

Fruit	General Comments	Ref. No.	Investigator	Institution	Best Dosage (M. Rad.)	Max. Dose for Acceptance	Acceptable Quality (Days)	Maximum Storage (Days)
GRAPES	Organoleptic effects above 0.3 Mrad. Sl. color change & mold inhibited without adverse effects on quality at 0.3 Mrad.	346 315	Gernon	QMC	0.46	-	10	-
GRAPEFRUIT	Slight quality changes above 0.5 Mrad.	346	Gernon	QMC	0.46	-	-	-
LEMONS	Skin discoloration & softening above 0.2 Mrad. after 12 days at 70°F.	346	Gernon	QMC	0.14	-	11	14
ORANGES	Doses above 0.5 Mrad. cause undesirable changes in texture & rind, sl. browning in color & off flavor development.	346	Gernon	QMC	0.14	-	-	33+
PEACHES	Mold & brown rot control are indicated above 0.3 Mrad. but off flavor develops at 70°F. storage.	346	Gernon	QMC	0.23	-	10	-
STRAWBERRIES	Minor changes occur in flavor texture & color at doses below 0.5 Mrad., molds are inhibited. A green tip maturity is best for irradiation.	111 390 52	Eukel Truelsen	App. Rad. Danish AEC	0.20 0.35	- -	7 9+	14 -

F. EXPERIMENTAL RADIATION PASTEURIZATION DATA OF THE SELECTED REFRIGERATED FRUITS

A major interest of this survey is the combined use of radiation processing, refrigeration and proper packaging to improve the storage life of fresh fruits. Table 15 is a compilation of experimental data which was used as a basis for estimating process requirements.

1. Radiation Dose

Experimental radiation-pasteurization work on fruits has been limited to those products that can withstand doses under one megarad without visible tissue damage or loss of flavor. Most fruits and vegetables show loss of appearance, flavor and texture when irradiated above this level. Inactivation of spoilage fungi through irradiation increases the storage life with minimum chemical or physical change of the tissues. The work reported in the literature indicates that there is an optimum dose level between that which extends storage life and that which produces undesirable product changes. The actual mechanisms by which product tissue is injured in inactivation of spoilage fungi is not known. Indications are that the action is similar at the cellular level. The extension of product storage life without tissue injury may be the result of partial inactivation of microorganisms when subjected to a pasteurization as compared to a sterilization treatment. The

effect of radiation on the tissue may extend the latent period of spore development or growth.

2. General Comments

Major causes of spoilage in citrus fruits are attributed to surface contamination by the Penicillium molds, P. digitatum and P. italicum. Radiation dosages required to kill mold spoilage microorganisms found on citrus fruit range between 100,000 and 2,000,000 rads. A 10,000 rad dose is required to control the growth of yeast. The natural color of the citrus fruit is generally unaltered at a dose level of 100,000 rads. The flavor of citrus fruits is generally unaffected at a level of 200,000 rads. Browning is evident at levels above 275,000 rads. Rind pitting and softening of texture is noted at doses above 300,000 rads.

The use of radiation for pasteurization of fresh produce remains an experimental tool until it is proved safe, feasible and economical. Fungi sensitivity to radiation, threshold levels of tissue injury, flavor changes and product packaging requirements merit additional work. Most fruits will tolerate a dose of 200,000 to 300,000 rads with little adverse effect.

G. ESTIMATED RADIATION PASTEURIZATION PROCESS FOR THE SELECTED FRUIT PRODUCTS

TABLE 16

ESTIMATED RADIATION PASTEURIZATION PROCESSING OF SELECTED REFRIGERATED FRUIT PRODUCTS

Fruit		Present Refrigerated Storage Life (Days)		Desired Refrigerated Retail Storage Life (Days)	Probable Irradiation Dose (M rad)			Probable Refrigerated Retail Storage Life After Irradiation (Days)		Possible Changes in Product Processing	Present Commercial Package	Possible Changes in Packaging Method
		Chill (32°F.)	Retail (40°F.)		Min.	Probable	Max.	Acceptable Quality	Maximum Storage			
GRAPES	(AM.) (Eur.)	64 -398 400 - 82	1-3	10	0.3	0.5	1.0	10	14	In Package Fumigation	Wood lugs Plastic Bags Fibreboard Boxes	Plastic Bags - Overwrapped trays-boxes
GRAPEFRUIT		90	4-5	14	0.3	0.5	0.7	10	14	Diphenyl treated package	Plastic and wash cloth bags Wood Boxes	Plastic Bags - Overwrapped boxes
LEMONS		97 - 400	8-10	14-21	0.1	0.2	0.5	11	14	Borax wash	Fibreboard carton Plastic Bags	Overwrapped trays
ORANGES		398-386	4-5	14	0.1	0.2	0.5	20	60	Borax wash - Diphenyl treated package	Plastic & wash Cloth Bags	Plastic-Bags - Overwrapped boxes
PEACHES		37 - 64	2-3	10	0.1	0.25	0.4	10	30	Chlorine water wash	Wood Lugs-Boxes and Baskets	Overwrapped trays - Boxes
STRAWBERRIES		33	1-2	10	0.1	0.25	0.4	10	30	Sorbic Acid Spray	Wood - Paper Plastic Baskets	Overwrapped boxes
TANGERINES		51 - 90	3-4	14	0.1	0.2	0.4	10	21	Borax wash - Diphenyl treated package	Plastic & wash Cloth bags	Plastic-Bags - Overwrapped boxes
TOMATOES	(MG.) (Ripe)	64 - 142 33 - 37	2-3 2-3	10	0.2	0.3	0.4	17	30	Chlorine water wash	Wood Lugs & Baskets Paper Trays	Plastic Bags Overwrapped trays

G. ESTIMATED RADIATION PASTEURIZATION PROCESS FOR THE SELECTED FRUIT PRODUCTS

Table 16 includes the probable radiation dose that may be used in processing the selected fruit products.

Short summaries of the radiation requirements follow:

1. Grapefruit

No noticeable changes were observed when grapefruit was irradiated at 500,000 rads. (346)

2. Lemons

Irradiation of lemons in a range between 100,000 and 200,000 rads prevented decay by P. digitatum without injury for 12 days at 75°F and 17 days at 55°F. The controls showed decay after three days at 75°F. Doses required to kill the fungi resulted in skin discoloration and softening of tissue. A 200,000 rad dosage is considered optimum for mold control and minimum radiation injury. (34, 35, 346)

3. Oranges

Irradiation of navel oranges in a range between 100,000 and 200,000 rads prevented decay by P. digitatum without injury for 20 days at 75°F and 65 days at 41°F. The controls showed decay after four days at 75°F. Doses required to kill the fungi resulted in skin discoloration and loss of texture. A 200,000 rad dosage is considered optimum for mold control and minimum radiation injury. (34, 35, 346)

4. <u>Tangerines</u>

No data on the irradiation of tangerines have been reported.

5. <u>Grapes</u>

Thompson seedless grapes when irradiated to 200,000 rads were considered acceptable after 4 weeks storage at 40°F. The fruits showed a loss of color when irradiated at 300,000 rads. No mold or off-flavor was noticeable at this level. Controls were inedible after four days due to growth of fungi. Research studies on control of Botrytis cinerea mold inoculated in Tokay grapes and treated at 500,000 rads show no adverse effect on quality. Inoculated grapes did not show rot development for ten days while controls were spoiled in four days when stored at 75°F. A 200,000 rad dosage is considered optimum for mold control and minimum radiation injury. (37, 315, 346)

6. <u>Peaches</u>

Irradiation of Elberta peaches in a range between 200,000 and 250,000 rads prevented decay by Rhizopus nigricians and Monilina for 30 days at 70°F. Controls showed decay after 10 days at 70°F. Doses required to kill the fungi resulted in skin discoloration, flavor changes and loss of texture. A 250,000 rad dosage is considered optimum for mold control and minimum radiation injury. (32, 35, 246, 316, 346)

7. <u>Strawberries</u>

Irradiation of strawberries in a range between 100,000 and 300,000 rads prevented decay by R.stolonifer for 40 days

at 40°F. Controls showed decay after 2 days at 40°F. Doses required to destroy the fungi resulted in loss of flavor, texture and color. A 250,000 rad dosage is considered optimum for mold control and minimum radiation injury. (37, 52, 111, 247, 316, 317, 390)

8. Tomatoes

Irradiation of pink tomatoes in a range between 100,000 and 300,000 rads prevented decay by common mold for 39 days at 70°F. Controls showed decay after 10 days at 70°F. Doses required to destroy the fungi resulted in loss of flavor and texture. A 300,000 rad dosage is considered optimum for mold control and minimum radiation injury. (35, 316, 317)

TABLE 17

A GUIDE TO THE APPLICABILITY OF FOOD PACKAGE TYPES FOR SELECTED RADIATION PASTEURIZED FRUITS

CITRUS AND TOMATOES

Packaging Requirements

	Permit Respi-ration	Minimal Off-Odors, Off-Flavors	Withstand Moisture Exposure	Prevent Moisture Loss	Prevent Insect Infestation	Protect Against Damage	Prevent Recontam-ination
1. Large Rigid Containers for Bulk use or Shipping Package for Consumer Units (Boxes, Crates, Lugs)							
Coated Paperboard		3	2		1	a	1
Corrugated Combined Paperboard		3	2		1	a	1
Wood		3		4	1	a	1
Wood with Insert Liner		3			1	a	1
2. Semi-Rigid Packages with Overwrap for Consumer End Use (Trays-Baskets)							
Plain Molded Paper Pulp		3	2		1	a	1
Coated Paperboard		3	2		1	a	1
Thermoformed Plastic		3			1	a	1
Wood		3			1	a	1
3. Flexible Packages for Consumer End Use (Bags, Pouches, etc.)							
Plastic Film		3			1	a	1
Coated Plastic Film		3			1	a	1
Mesh with Insert Liner		3			1	a	1
Coated Paper		3	2		1	a	1
Plain Paper		3	2		1	a	1

PEACHES

Packaging Requirements

	Permit Respi-ration	Minimal Off-Odors, Off-Flavors	Withstand Moisture Exposure	Prevent Moisture Loss	Prevent Insect Infestation	Protect Against Damage	Prevent Recontam-ination
1. Large Rigid Containers for Bulk use or Shipping Package for Consumer Units (Boxes, Crates, Lugs)							
Coated Paperboard		3	2		1	a	1
Corrugated Combined Paperboard		3	2		1	a	1
Wood		3			1	a	1
Wood with Insert Liner		3			1	a	1
2. Semi-Rigid Packages with Overwrap for Consumer End Use (Trays-Baskets)							
Plain Molded Paper Pulp		3	2		1	a	1
Coated Paperboard		3	2		1	a	1
Thermoformed Plastic		3			1	a	1
Wood		3			1	a	1
3. Flexible Packages for Consumer End Use (Bags, Pouches, etc.)							
Plastic Film		3			1	a	1
Coated Plastic Film		3			1	a	1
Mesh with Insert Liner		3			1	a	1
Coated Paper		3	2		1	a	1
Plain Paper		3	2		1	a	1

Note: The package types listed above should perform satisfactorily with only minimum additional evaluation with the exceptions of the problem areas indicated.

Package Design Comments

a. Cushioning materials may be required to separate and support consumer units in secondary shipping container.

Package Material Comments

1. Magnitude of problem has not been investigated thoroughly.
2. Material may become saturated and lose strength in storage, however, some moisture absorbence may be beneficial to product.
3. Organoleptic contribution from package may be minimal problem, however, definitive information is not presently available.
4. Without an insert liner the moisture loss of the product can be excessive.

Remarks: Surface irradiation as contrasted with irradiation of the whole cross section of the fruit presents package design considerations for which no data is available.

TABLE 17a

A GUIDE TO THE APPLICABILITY OF FOOD PACKAGE TYPES FOR SELECTED RADIATION PASTEURIZED FRUITS

GRAPES

Package Type	Permit Respi-ration	Minimal Off-Odors, Off-Flavors	Withstand Moisture Exposure	Prevent Moisture Loss	Prevent Insect Infestation	Protect Against Damage	Prevent Recontam-ination
1. Large Rigid Containers for Bulk use (Boxes, Crates, Lugs)							
Coated Paperboard		3	2		1	a	1
Corrugated Combined Paperboard		3	2		1	a	1
Wood		3		4	1	a	1
Wood with Insert Liner		3			1	a	1
2. Semi-Rigid Packages with Overwrap for Consumer End Use (Trays-Baskets)							
Plain Molded Paper Pulp		3	2		1	a	1
Coated Paperboard		3	2		1	a	1
Thermoformed Plastic		3			1	a	1
Wood		3			1	a	1
3. Flexible Packages for Consumer End Use (Bags, Pouches, etc.)							
Plastic Film		3			1	a	1
Coated Plastic Film		3			1	a	1
Mesh with Insert Liner		3			1	a	1
Coated Paper		3	2		1	a	1
Plain Paper		3	2		1	a	1

STRAWBERRIES

Package Type	Permit Respi-ration	Minimal Off-Odors Off-Flavors	Withstand Moisture Exposure	Prevent Moisture Loss	Prevent Insect Infestation	Protect Against Damage	Prevent Recontam-ination
1. Large Rigid Containers for Bulk use (Boxes, Crates, Lugs)							
Coated Paperboard		3	2		1		1
Corrugated Combined Paperboard		3	2		1		1
Wood				4			
Wood with Insert Liner		3			1		1
2. Semi-Rigid Packages with Overwrap for Consumer End Use (Trays-Baskets)							
Plain Molded Paper Pulp		3	2		4	a	1
Coated Paperboard		3	2		1	a	1
Thermoformed Plastic		3			1	a	1
Wood		3			1	a	1

Note: The package types listed above should perform satisfactorily with only minimum additional evaluation with the exceptions of the problem areas indicated.

Package Design Comments

a. Cushioning materials may be required to separate and support consumer units in secondary shipping container.

Package Material Comments

1. Magnitude of problem has not been investigated thoroughly.
2. Material may become saturated and lose strength in storage, however, some moisture absorbence may be beneficial to product.
3. Organoleptic contribution from package may be minimal problem, however, definitive information is not presently available.
4. Without an insert liner the moisture loss of the product can be excessive.

H. A GUIDE TO THE APPLICABILITY OF FOOD PACKAGE TYPES TO THE SELECTED REFRIGERATED, RADIATION PASTEURIZED FRUIT PRODUCTS

In Tables 17 and 17a, the container requirements are compared with package types which have achieved high volume usage in packaging of foods similar in packaging requirements to the fruit products selected for study in the AEC program. The estimates of performance for the package types reflect the information reviewed on Part I, the previous sections of Part II, and the past experience of Continental Can Company in furnishing packages to the food processing industry. In most package type categories a variety of specific materials are available which will likely perform adequately.

Definitive material costs and non-technical aspects of food packaging are not within the scope of this study.

The major problem of packaging radiation-pasteurized fruits is to provide for product respiration requirements. The perforated plastic film packages presently being used are not considered ideal for irradiated products because of possible recontamination by fungi. The package requirements must also consider storage of the fruit for several weeks at refrigeration temperatures followed by extended transport before marketing.

The characteristics of a satisfactory package for radiation-pasteurized fruits are that it will:

1. protect the product from physical damage.
2. provide good sealing properties.
3. permit efficient packaging.
4. permit good thermal conductivity.
5. prevent product moisture loss and fogging.
6. maintain a proper modified atmosphere.
7. be unaffected by ice or chill.
8. prevent microbiological recontamination.
9. prevent insect infestation.

For those fruit products which would be packaged in consumer size units prior to irradiation and subsequently contained in a multiple packed shipping container, the packaging materials (particularly plastic and paper) which are presently used should satisfy most of the functional requirements unless recontamination of the fruit after packaging is found to be of sufficient importance that perforations in the packaging material could not be permitted. Some fruits may be irradiated immediately prior to the time that they are packaged for shipment. In this case, presently established package engineering concepts should be adequate.

It has been suggested that surface irradiation of citrus, peaches and tomatoes would be a possible method of reducing the fungus population on the skin of the fruit to extend the refrigerated shelf life of the product (116). The use of this technique for fruits packaged prior to irradiation would require extensive investigation

of the package design and appropriate thickness of packaging materials. It is expected that the physical and chemical properties of the packaging materials would not be appreciably affected in such an arrangement.

It is not presently possible to establish exact dimensions of packages for any of the fruits which would be packaged prior to irradiation since the permissible dose variation within a package unit and with the individual fruit, as well as the most economical source configuration, has not been determined.

I. Conclusions

1. Presently known package engineering can provide most of the functional requirements for radiation-pasteurized fruits. However, new materials and new package designs should be evaluated for applicability as they become available commercially.
2. Controlled respiration is a major problem in the design of packages for unirradiated fresh fruit, and will also be a problem for radiation-pasteurized fruit.
3. If recontamination of fruit after radiation-pasteurization is found to be a serious problem, major design and material modifications may be required.
4. If irradiation is performed prior to packaging, controlled sanitary conditions must be employed.
5. Organoleptic contribution from the package material to the fruits probably will be minimized by the ventilation necessary for proper packaging, the probable radiation dose range from

0.25 megarad to 0.5 megarad for fruits, and the natural protective surface of the fruits.

6. Presently available data on radiation-pasteurization of fruits are insufficient to specify exact geometric package design.

PART III

PART III

A. SUMMARY OF ADDITIONAL INFORMATION NECESSARY FOR OPTIMIZATION OF PACKAGING FOR THE SELECTED RADIATION PASTEURIZED FOODS

It has been reported that the following information necessary for optimization of packaging is within the scope of contracts which have been initiated by the AEC:

1. Dose Distribution in Food Package

   Permissible variation of radiation dose in individual food containers for each food item. This variation directly affects the geometric shape of the food package.

2. Recontamination of Packaged Fruit Products

   The significance of possible recontamination of fruit products after irradiation in subsequent storage, shipping, and handling.

3. Packing Environment for Fishery Products

   The relative merits of vacuum packing and air packing of fishery products.

In addition to the aforementioned work undertaken in present AEC contracts, the following information is deemed necessary for demonstrating commercial feasibility of radiation-pasteurization of foods and for optimization of packaging for the selected food items:

4. Extractives

   In addition to an assurance that packaging materials will retain desirable physical and chemical properties following their irradiation, it is essential that the potential migration of

components and possible degradation products from packaging materials into foods be carefully evaluated.

The necessity of obtaining clearance for this new use of packaging materials was established by the Food and Drug Administration, Department of Health, Education, and Welfare at a joint meeting with AEC and Continental Can Company personnel on April 25, 1962.

The initial step in securing information for an appropriate regulation permitting the use of irradiated packaging materials is to perform extractive studies of approved packaging materials.

Detailed testing procedures are presented in section B. of this part of the report.

5. Effect of Irradiation on Colorants used in conjunction with food packaging materials

A limited amount of data are available on the behavior of colorants in food irradiation environments. From related experimental information significant detrimental changes are unlikely to occur at radiation-pasteurization dosage levels; however, during the AEC sponsored food-technology investigations observations of any significant changes in colorant behavior should be denoted for further considerations.

6. Organoleptic Deficiencies of Polymeric Materials

TABLE 18

SUMMARY OF OFF-GAS, OFF-FLAVOR, AND OFF-ODOR EVALUATIONS OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENTS REPORTED IN THE LITERATURE

PACKAGING MATERIAL	DOSE	Environ	OFF-GAS: Relative Amounts** of Gaseous Products Produced from Irradiated Packaging Materials (** largest amount shown is approximately 30 micromoles / gram of sample)	OFF-FLAVOR *: Comments on Flavor of Distilled Water Irradiated in Packaging Materials — Non-Irradiated	Irradiated (1 to 6 megarad)	Non-Irradiated	Effect of Increasing Radiation Dose and Storage at 73°F.	Effect of Storage at 40°F.	OFF-ODOR *: Relative Change in Odor Intensity of Non-Irradiated and Irradiated Film — DOSE (megarad) 0, 1, 3, 6
NYLON 6	S	V		normal	paper or straw				
POLYESTER	S S	A V				None	None	None	
POLYSTYRENE	S S	A V				Off-Flavor	Increases Off-Flavor	Reduces Off-Flavor	
POLYMONOCHLOROTRI-FLUOROETHYLENE	S S	A V		normal	extremely weak chlorine				
RUBBER HYDROCHLORIDE	S S	A V		--	straw like				
NYLON 66	S	V							
POLYVINYLIDENECHLORIDE	P S S	A A V				Off-Flavor	Increases Off-Flavor	Reduces Off-Flavor	
POLYESTER (POLY-ETHYLENE COATED)	P S S	A A V		normal	weak perfume				Very Objectionable Off-Odor at 1.5 and 2.0 m rad
POLYETHYLENE (LOW DENSITY)	P S S	A A V		normal	faintly medicinal	Off-Flavor	Increases Off-Flavor	Reduces Off-Flavor	
POLYETHYLENE (HIGH DENSITY)	P S S	A A V		normal	slightly oily or papery	Off-Flavor	Increases Off-Flavor	Reduces Off-Flavor	
POLYPROPYLENE	S	V							
POLYETHYLENE (MED. DENSITY)				normal	faintly medicinal				
POLYVINYL CHLORIDE				very slight off-flavor	extremely weak-bitter				
CELLOPHANE (POLY-ETHYLENE COATED)				bitter	bitter;phenolic				
KRAFT (UNBLEACHED-BLEACHED POLYETHYL-ENE COATED)				normal	faintly medicinal cardboard				
PAPER (COATED)-AL. FOIL POLYETHYLENE				normal	very weak straw				
POLYETHYLENE-POLY-VINYLIDENE CHLORIDE COPOLYMER				normal	weak;oily				
POLYETHYLENE-AL. FOIL-POLYESTER-POLYETHYL-ENE				normal	moderate oily				
CELLOPHANE						Off-Flavor	Increases Off-Flavor	Reduces Off-Flavor	

V - Vacuum
A - Air
Intensity of Odor Rating

P - Pasteurization Range (1 megarad or less)
S - Sterilization Range (3 to 6 megarad)

* NOTE: Characteristic odors and flavor components are associated with most organic packaging materials used for conventionally processed foods. Proper selection and modification of packaging materials are employed to obtain "acceptable" materials for specific foods.

6. Organoleptic Deficiencies of Polymeric Materials

Generally speaking, substances contributing to off-odors and in some cases off-flavors can be generated by the action of radiation on polymeric materials at the radiation-pasteurization level (1 megarad or less) in varying amounts depending upon the specific composition of the packaging material. The amount and nature of off-gases generated from a polymeric material in a radiation environment can vary markedly even within one polymer type depending upon the manufacturing method, storage history, and types of additives used in the material. One of the most significant factors is the presence of oxygen in the polymer and the environment. It is quite probable that many polymers which normally cross-link upon irradiation may actually degrade or go through chain scission in the presence of oxygen. The terms degraded or cross-linked used in classifying polymers refer to the dominate process since both are actually occurring in these materials during irradiation. Much of the experimental work in evaluating the effects of radiation on polymers excluded oxygen since it can provide a complex result in many cases. The data indicate that at the 1 megarad or less dose level the chemical species contributing to organoleptic deficiencies is a dominant concern.

The use of an inert gas atmosphere during a radiation may not be economically or technically justified. Even in a vacuum, off-gases are

produced. There is only a shift in their type and quantity that is experienced in excluding oxygen. Furthermore, the dose rate may play a role which has not been thoroughly investigated in this usage of polymeric materials. It would seem reasonable that the higher the dose rate, the smaller would be the effect of oxygen since its availability to the polymer molecule depends upon its diffusion rate to the active site.

Since irradiating the food by itself can lead to off-flavor and off-odor, isolation of those off-flavor and off-odor components which are due entirely to the packaging material is difficult.

In Table 18 a summary of organoleptic factors is presented. (38, 39, 118, 197, 389)

B. RECOMMENDATIONS FOR NEEDED PACKAGING RESEARCH AND TESTING

To encourage commercial exploitation of radiation-pasteurization of the ten selected food items, it is recommended that the AEC Division of Isotopes Development undertake the following additional projects in packaging research:

1. Extractives Studies

As a part of this contract, Continental Can Company requested the Food and Drug Administration, Department of Public Health, Education, and Welfare to consider the requirements for effectively petitioning the agency for an appropriate regulation to permit the use of irradiated packaging materials in contact with food. The initial step in acquiring information for an appropriate regulation is to perform extractive studies of approved packaging materials with food simulating solvents to determine if there is any significant change in the extent and nature of extractives using test conditions which reflect the conditions of use in this new food processing method.

It was the opinion of the FDA that the following test conditions should effectively exaggerate the conditions of use:

Radiation Dose

A total dose of 1.0 megarad should be used for a screening test and any material that fails at this level should be further checked at 0.5 megarad. A dose of 1.0 megarad should be sufficient exaggeration

of the practical radiation pasteurization dosage level for any of the products under consideration.

Energy of Incident Radiation

The energy of the incident radiation used in the testing program should not exceed 2.2 Mev for gamma rays or 5 Mev for electron sources.

Food Simulating Solvents

Water to simulate water containing food products, heptane for simulating fat containing foods, and citric acid solution (pH-3.5) should be sufficient to include the food products in the AEC program.

Storage Period

Cells containing irradiated packaging materials in contact with food-simulating solvent and similarly prepared cells containing unirradiated packaging materials should be stored for six weeks in order to equal, or exaggerate, the anticipated maximum commercial storage period.

Storage Temperature

Sample materials in the irradiated cell should be maintained at 70°F to exaggerate refrigerated storage.

Relative Humidity

Samples should be stored at a relative humidity of 75% in order to minimize water vapor transmission through the flexible barrier packaging material and thus be more consistent with the transmission characteristics at the anticipated commercial temperatures of 30°F to 40°F.

Packaging Materials Recommended for Study of Extractives

In initiating this testing program it is reasonable to consider those materials which have a known status with respect to toxicological safety when used in contact with food.

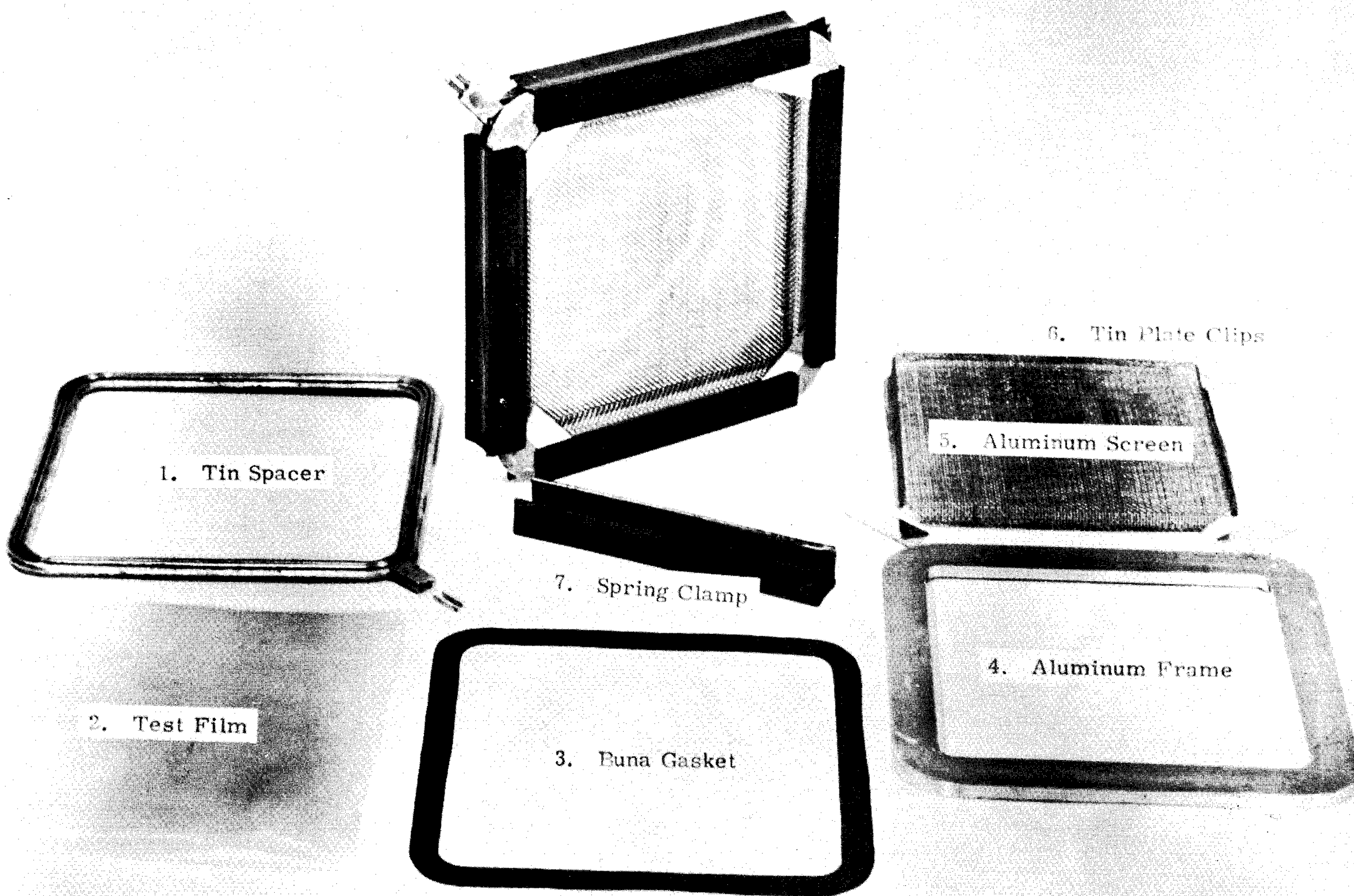
The following list of packaging materials is recommended for extractives studies for radiation-pasteurized foods:

Cellulosic Materials
Cellophane, plain
Cellulose acetate
Glassine
Waxes
Paraffin-microcrystalline
Polymers
Polyolefin-Polyethylene
Polystyrene
Polyvinylidene Copolymers (e.g.Saran)
Rubber Hydrochloride
Oleoresinous enamel - "C" enamel comprising drying oil with a maleic resin ester, and zinc oxide

The following description of an appropriate extraction cell and an estimated cost for performing this type of study is presented for the use of the AEC in budgeting their program and in assisting the contractor selected for these studies. Thus, this is not a proposal for contract work.

Extraction Cell

None of the conventional extraction cells designed to simulate thermal processing and storage is well suited to the study of the effects of radiation on a packaging material in contact with a food-simulating solvent. These cells all interpose an excessive radiation absorption barrier between the radiation source and the



IRRADIATION TEST CELL AND COMPONENTS

FIGURE 2

packaging material and, in addition, often have an unfavorable ratio of volume to area. Consequently, some five years ago, Continental Can Company undertook the development of a new type of cell specifically designed for irradiation and extractives studies.

The test cell is designed to hold two 7-inch squares of material in contact with aerated, deionized distilled water in a structure suitable for irradiation in commercially available equipment with either electrons, such as from a linear accelerator source, or gamma rays from a radioactive source such as cobalt-60. The assembly and details of the cell are shown in Figure 2. A 7-inch square of film is placed on each side of the pure tin spacer and assembled with aluminum side frames held together by steel spring clamps. Buna rubber gaskets between the films and side frames provide sufficient cushion to seal the films or laminates to the tin separator and to give a leak-proof container for holding distilled water or other liquid. Removable, dished, aluminum wire screens held in place by tin plate clips are inserted on each side to prevent the flexible film from bulging when the container is filled with water during handling, transportation, and storage exposure. At the same time, the screens are not a barrier to the

normal transmigration of air and water across the film being tested.

Exposure to electrons is carried out with the cell in a horizontal position and the top screen removed to prevent interference with the passage of the electrons or beta rays which have limited penetration. The more penetrating gamma rays do not require removal of the screens, and this exposure may be performed with the cell in either a vertical or a horizontal position. Two holes in one corner of the spacer permit venting of air from the container while it is being filled with water; these holes are closed with tin taper pins after filling.

The cell dimensions were selected so that 6-inch strips of exposed film may be cut for mechanical testing. The spacer thickness of 1/4-inch gives a thin enough layer of water to provide adequate penetration by beta rays. At the same time it provides a volume area ratio (2.8 ml/sq in.) which previous work on can enamel extractives has shown to give accurate results.

Because most packaging materials are extractable only to the extent of a few hundredths of one percent, it is necessary to combine the aqueous extracts from 4 cells in order to obtain sufficient material for accurate weighing of material extracted and for infrared identification if the latter is required. Infrared identification of extractives is performed only if their level is toxicologically significant. Furthermore, it is essential that these micro quantities of extract be

uncontaminated by extraneous material from the cell or from radiation-catalyzed products originating from the materials of the cell. Consequently, the spacer is made of pure tin in line with previous extractability experience, and the gaskets are placed outside the test films. When samples of tin plate are subjected to irradiation, it will be necessary to use inside gaskets to form a water-tight seal. By then the results of tests on plastic materials will be completed and these will guide the selection of a suitable gasket.

The cell proved admirably suited for its intended purpose since it has the following features:

a. Packaging materials can be irradiated in contact with food-simulating solvents inside the package and with air outside.

b. Absorption of radiation by the cell is almost nil.

c. The ratio of volume to area permits recovery of a sufficient amount of extractives for determination and characterization since each cell exposes 72 square inches of packaging material to some 200 ml of food-simulating solvent or 2.8 ml/sq in. In practice, four such cells constitute one sample.

d. Contamination of the food-simulating solvent by the cell is negligible.

e. Organoleptic changes in the food-simulating solvent can be evaluated.

f. Off-gases can be recovered.

g. From the same experiment, adequate samples of packaging materials are obtained for physical and mechanical testing.

h. Storage of cell and contents during a post-irradiation period closely simulates commercial storage in that the outside is exposed to the atmosphere.

Estimated Cost of Extractives Studies

The following estimates are based upon our past experience with the extractives studies similar to those outlined:

Capital Investment (special cells)

	Replication	
Cells per experimental run	4	
Runs per sample	3	
Blanks	2	
Samples per week	1	
Weeks per sample	6	
	144	
at $150 / cell		$21,600

Expense Per Sample (in groups of 6)

Preparation of cells , exposure to radiation, storage, determination of extractives, infrared identification when level of extractives is toxicologically significant, optical and mechanical measurements

$1600 per sample	9,600
Preparation of Report	20,000

(This estimate includes the delivery of 550 copies)

Total Cost

6 samples	$51,200
12 "	60,800
18 "	70,400
24 "	80,000

In the above estimates it is assumed that radiation facilities will be rented and that the contracting laboratory possesses all other equipment for the conduct of the extractives studies with the exception of the special cells.

2. Organoleptic Aspects of Food Packaging Materials

It has been reported by the Quartermaster Food and Container Institute that laboratory quantities of polyethylene with "anti-rad" additives have been produced and are currently under investigation. Preliminary results have shown an improvement in off-odor development.

It is recommended that the investigation of the use of "anti-rads" be extended to other polymeric materials and organoleptic screening tests of logical material selections should be performed in conjunction with the food technology investigations now in progress under AEC contractural agreements.

3. Merchandising Aspects of Packaged Radiation Pasteurized Fishery Products

Because the introduction of a product preserved by a new method should be easily and distinctly recognized by the consumer as "different" from existing forms of the same basic product preserved by more conventional methods, the package should provide this measure of "difference." The definition of what form this "difference" should take is in the realm of merchandising and can best be determined by assaying a cross section of final consumers. This assay should be a form of market research aimed at determining consumer acceptance of different approaches to packaging (i.e. fish in bulk, in rigid metal or board containers, in flexible pouches, etc.).

4. <u>A Continuing Program of Cooperation with the Packaging and Food Industries</u>

A substantial portion of the information on the behavior of packaging materials in food irradiation environments has been developed by food package manufacturers. An effective method of achieving optimization of packaging for radiation-pasteurized foods is to enlist the technical capabilities of food package manufacturers.

It is recommended that the AEC establish a working committee on packaging radiation processed foods with the following membership and objectives:

a. <u>Membership</u>

Qualified technical representatives from rigid food container, flexible food container, semi-rigid food container manufacturing organizations, fishery products investigators, fruit products investigators, and radiation source designers from the AEC sponsored program.

b. <u>Objectives</u>

(1) To review the results of the radiation-pasteurization food-technology investigations as they relate to packaging.

(2) To advise the radiation source designer on package design considerations.

(3) To establish a series of definitive specifications for

package and packaging materials for radiation-pasteurized foods.

(4) To provide liaison with package manufacturers through the issuance of pertinent information as it becomes available.

With proper administration, this working committee can enhance the rapidity with which commercial feasibility is achieved and will provide the basis of an effective competitive situation in the packaging industry to achieve commercial exploitation of radiation-pasteurized foods.

BIBLIOGRAPHY

(1) AEBERSOLD, P. C., et al, "Ad Hoc Panel Report to the Interdepartmental Committee on Radiation Preservation of Foods on a National Civilian Radiation Processed Foods Program", Hearings before the JCAE Cong. of the U.S., Part 1, Jan., 1960

(2) AEBERSOLD, P. C., "AEC Program for Radioisotopes Technology Development", Preprint Paper #47, Nuclear Engin. & Sc. Conf., April, 1960

(3) AEBERSOLD, P. C., "The USA Research Program on Low Dose Radiation Processing of Food", Symposium on Isotopes Applications Tenth Pacific Sc. Cong., Honolulu, Aug., 1961

(4) ALBANO, G. A., "Monthly Summary of Chicago's Wholesale Market Fresh and Frozen Fishery Products Receipts, Prices, and Trends," USDI Bureau of Commercial Fisheries, March, 1961

(5) AMBROSE, A. M.; BOOTH, A. N.; DE EDS, F.; and COX, A. J., "A Toxicological Study of Biphenyl, A Citrus Fungistat", Microbiology of Food, 25, 3, May-June, 1960

(6) ANDERSON, A. W., "Fresh and Frozen Fish Buying Manual, USDI Fish and Wildlife Service, Circular #20

(7) ANDERSON, D. L.; SHAFFER, P. F., "Improved Handling of Frozen Foods in Retail Stores", USDA, Marketing Research Rpt. #104, Sept., 1955

(8) ANDERSON, R. E.; and HARDENBURG, R. E., "Effect of Various Consumer Baskets, Film Wraps, and Crate Liners on Quality of Strawberries", Proceedings of the Amer. Soc. for Hort. Sc., 74, 1959

(9) ANDERSSON, K.; and DANIELSON, C. E., "Storage Changes in Frozen Fish: A Comparison of Objective and Subjective Tests", Food Tech., 15, 2, Feb., 1961

(10) Anon., "Upturn in Pre-Packaging", Modern Packaging, 33, 11, June, 1960

(11) Anon., "Shrink-Film Tray Pack", Modern Packaging, July, 1960

(12) Anon., "Now: Polystyrene Film for Produce", Modern Packaging, 33, 6, Feb., 1960

(13) Anon., "U.S. Fruit Acreage - Crops - Crop Utilization - Grower Prices", Yearbook Number, Canner Packer, Sept., 1960

(15) Anon., "Industry Reference Data", Yearbook Number, Canner Packer, Sept., 1960

(15) Anon., "Peaches Packed Like Cupcakes", Packaging Parade, Dec., 1948

(16) Anon., "The Storage of Fresh Fruits", Packaging Abstracts, 18, 9, Sept., 1961

(17) Anon., "A New Type Strawberry Container", Packaging Abstracts, 18, 5, May, 1961

(18) Anon., "The Use of Ionizing Radiations for Food Preservation", Food & Agric. Organization Conf., Nov., 1958, Chemistry & Industry, Feb., 1959

(19) Anon., "Fish in Film, Modern Packaging, Jan., 1959

(20) ARNOLD, A. H., "Pasteurization by Radiation of Cooked and Prepared Foods", U. S. Army, Quartermaster Corps, Contract #68, Final Rpt., Jan., 1960

(21) ARONOW, W. A.; and BRYAN, J. E., "Pre-Packaging Tomatoes", USDA, Marketing Research Rpt., #20, Oct., 1952

(22) ARTANDI, C., Ph.D; and STONEHILL, A. A., Ph.D., "Rigid Polyvinyl Chloride as a Dosimeter", Proceedings of the 1958 Accelerator Conf., Oct., 1958

(23) ASTM, "Exposure of Polymeric Materials to High Energy Radiation", ASTM D 1672-59 T, Revised, Sept. 10, 1959

(24) AYRES, J. C.; and PEIRCE, L. C., "Effect of Packaging Films and Storage Temperatures on the Ripening of Mature Green Tomatoes", Food Tech., 14, 12, Dec., 1960

(25) AYRES, J. C., "Use of Coating Materials or Film Impregnated with Chlortetracycline to Enhance Color and Storage Life of Fresh Beef", Food Tech., 13, 9, Sept., 1959

(26) BARBER, S. W.; FORRY, K. E.; and DEGERING, E. F., "Effects of Electron Bombardment on Elasticity and Mechanical Damping of Certain Glasses", Amer. Ceramic Soc. Symposium on Radiation Effects, Oct., 1959

(27) BARGER, W. R.; HARVEY, J. M.; and RINGEL, S. M., "Shipping Mature Green Tomatoes by Rail", Agric. Marketing, 4 , 11, Nov., 1959

(28) BARGER, W. R.; HARVEY, J. M.; and RINGEL, S. M., "Transit Temperatures of California Mature Green Tomatoes Shipped by Rail", USDA, Marketing Research Rpt. #349, July, 1959

(29) BARKER, R. S.; and RICHARDSON, D. A., "Effect of Gamma Radiation on Spectral Transmission of Some Commercial Glasses", Jl. of the Amer. Ceramic Soc., 44, 11, Nov., 1961

(30) BAUTISTA, F. R.; THOMPSON, R. H.; and CAIN, R. F., "Changes in Amino Nitrogen Total Soluble Nitrogen and TCA-Soluble Nitrogen Content of Beef as Influenced by Pre-Irradiation Heating, Irradiation Level and Storage at 34°F., Jl. Food Sc. 26, 1, Jan.-Feb., 1961

(31) BENDER, M.; MIYAUCHI, D. T.; and CARVER, J. H., "Progress Report on Radiation Pasteurization & Sterilization of Seafood", Quick Frozen Foods, 20, 11, June, 1958

(32) BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; and WRIGHT, W. R., "Effects of Gamma Radiation on Brown Rot and Rhizopus Rot of Peaches and the Causal Organisms", Phytopathology, 49, June, 1959

(33) BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; and WRIGHT, W. R., "Effects of Gamma Radiation on Some Important Potato Tuber Decays", Amer. Potato Jl. 36, 9, Sept., 1959

(34) BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; and WRIGHT, W. R., "Factors of Influencing the Use of Gamma Radiation to Control Decay of Lemons and Oranges, Phytopathology, 49, Feb., 1959

(35) BERAHA, L.; SMITH, M. A.; and WRIGHT, W. R., "Gamma Radiation Dose Response of Some Decay Pathogens", Phytopathology, 50, 6, June, 1960

(36) BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; and WRIGHT, W. R., "Gamma Radiation for Possible Control of Post Harvest Diseases of Lemons, Oranges, Strawberries, Grapes, and Peaches", Phytopathology, 47, 1957

(37) BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; WRIGHT, W. R.; and HEILIGMAN, F., "Gamma Radiation in the Control of Decay in Strawberries, Grapes and Apples, Food Tech., 15, 2, Feb., 1961

(38) BERSCH, C. F.; STROMBERG, R. R.; and ACHHAMMER, B. G., "Effect of Radiation on Plastic Films", Modern Packaging, Aug., 1959

(39) BESSE, A. L.; and THOMPSON, D. F., "Packaging for Irradiated Subsistence Items", U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Rpt. #5, March, 1958

(40) BIALE, J. B.; and YOUNG, R. E., "Critical Oxygen Concentrations for the Respiration of Lemons", Amer. Jl. of Botany, 34, 6, June, 1947

(41) BIALE, J. B., "The Physiological Requirements of Citrus Fruits", Citrus Leaves, July, 1954

(42) Biostatistical Section, "Statistical Report of Fresh, Canned, Cured and Manufactured Fishery Products Year 1960," State of Calif., Dept., of Fish & Game, Circular #35, 1961

(43) BITTING, H. W., "New Developments in the Frozen Food Industry...", USDA, Marketing Research Rpt. #236, May, 1958

(44) BOGARDUS, R. E., "Wholesale Fruit and Vegetable Warehouses - Guides for Layout and Design", USDA, Marketing Research Rpt. #467, Aug., 1961

(45) BOVEY, F. A., "Effects of Ionizing Radiation on Natural and Synthetic High Polymers", Interscience Publishers, Inc., N.Y., 1958

(46) BOWMAN, R. E., "How Radiation Affects Engineering Materials", Materials in Design Engin., Manual #173, July, 1960

(47) BRATLEY, C. O., "Refrigeration of Pre-Packaged Fruits and Vegetables", Refrigerating Engin., Dec., 1946

(48) BRATZLER, L. J.; RAPHAEL, H. J.; and COSTILOW, R. N., "Dip Coat Packaging of Irradiated Foods", U. S. Army, Quartermaster Corps, Project #0.1. 6169 Rpt. #10, May, 1960

(49) BREAKIRON, P. L.; and HOECKER, R. W., "A Comparative Study of Packing, Transportation & Refrigeration Costs of Bushel Baskets & Wire-Bound Boxes for Transportation of Peaches", USDA, Marketing & Facilities Research Branch, Feb., 1950

(50) BRIDGES, A. E.; OLIVO, J. P.; and CHANDLER, V. L., "Relative Resistances of Microorganisms to Cathode Rays II. Yeasts and Molds", Applied Microbiology, 4, 3, May, 1956

(51) BRILLINGER, J. H.; KALBER, W. A.; and LEYDON, A. J., "Effect of Radiation on the Physical Properties and the Sealing of Cans", U. S. Army, Quartermaster Corps, Project #7-82-01-002, Final Rpt., July, 1958

(52) BRODY, A. L., "Evaluation of Shelf Life of Irradiated Food", U. S. Army, Quartermaster, Corps, Project #7-84-01-002, Final Rpt., July, 1958

(53) BRODY, A. L., "Present Status of Radiation Preservation", Atomic Industrial Forum, Conf., Paper #57 - AIF-12, Oct., 1957

(54) BROMELL, J. R., "Survey of Wholesale Grocers' Profit and Loss Figures", Compilation and Analysis of 1955 & 57 Operating Results, U. S. Wholesale Grocers' Assoc., Inc., Washington, D. C.

* BROOKE, R. O.

(55) BROOKER, M. A.; and GILBRAITH, K.M., "Factors Influencing the Method of Transportation Used in Marketing Fresh Florida Citrus", Univ. of Fla., Agric., Experiment Sta., Bulletin 549, Sept., 1954

(56) BROOKS, H., "Nuclear Radiation Effects in Solids", Annual Review of Nuclear Sc., 6, 1956

(57) BROWN, E. E.; and THOMAS, W. H., "Moisture-Resistant Corrugated", Modern Packaging, 32, 5, Jan., 1959

(58) BROWNE, A. E.; CROW, W. C.; LENNARTSON, R. W.; NEWEL, S. R., et.al "Marketing - The Yearbook of Agriculture 1954", USDA, 1954

(59) BROWNELL, L. E.; and PUROHIT, S. N., "Combining Gamma Radiation, Refrigeration", Refrigerating Engin., June, 1956

(60) BROWNELL, L. E.; and PUROHIT, S. N., "High Radiopasteurization as a NEW Food Process", USAEC, Contract #AT(11-1)-162, C00-210, Oct., 1955

(61) BROWNELL, L. E.; NEHEMIAS, J. V.; and BULMER, J. J., "The Design of a Gamma Irradiation Facility for the Control of Insect Infestation in Flour, Meal, or Grain", USAEC, AECU-3050, Project #1943-7, Contract #AT(11-1)-162, May, 1955

(62) BROWNELL, L. E.; KEMPE, L. L.; and GRAIKOSKI, J. T., "Gamma Rays: The Hope of Researchers to Lengthen Refrigerated Life of Fresh Foods", Refrigerating Engin., March, 1955

(63) BROWNELL, L. E.; NEHEMIAS, J. V.; and BULMER, J. J., "Proposed New Methods of Wholesaling Fresh Meat Based on Pasteurization by Gamma Irradiation" USAEC, AECU-3043, Project 1943-7, Contract #AT(11-1)-162, Dec., 1954

(64) BROWNELL, L. E.; KUIPERS, K.; and EZMAN, L., "Radiopasteurization of Food", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #5, July, 1958

(65) BROWNELL, L. E.; KUIPERS, K.; BURCHFIELD, A.; JUDGE, P., et al "High Radiopasteurization of Foods", U. S. Army, Quartermaster Corps, Project # DA-19-129-AM-756, Final Rpt., Sept., 1957

(66) BRUNELET, L.; and VIDAL, P., "Some Aspects of the Problem of Packaging Food Products Which Have Been Sterilized by Ionizing Radiation", USAEC, AEC-tr-3691, June, 1959

(67) BRUNTON, D. C.; DONOVAN, J.; and VOYVODIC, L., "Design Experience of a Multi-Mecacurie Radiation Facility", Large Radiation Sources in Industry, 1, International Atomic Energy Agency, 1960

(68) BULL, R. L.; and GLADING, G. R., "Directory of Research Reports Relating to Produce Packaging", Produce Packaging Assoc., Revised Edition, May, 1959

(69) BURK, M. C., "Consumption of Processed Farm Foods in the United States", USDA, Marketing Research Rpt. #409, June, 1960

(70) BURK, M. C., "Trends and Patterns in U. S. Food Consumption", USDA, Agric. Handbook #214, June, 1961

(71) BURNS, E. E.; and DESROSIER, N. W., "Maturation Changes in Tomato Fruits Induced by Ionizing Radiation", Food Tech., 11, 6, 1957

(72) BYOIR, C., & Associates, Inc., "The Food Industries' Challenge to Packaging", Folding Paper Box Assoc. of Amer., Jan., 1956

(73) BYOIR, C., & Associates, Inc., "Pre-Packaging of Fresh Fruits and Vegetables", Folding Paper Box Assoc. of Amer., Nov., 1957

(74) BYSTEDT, J.; SWENNE, L.; and AAS, H. W., "Determination of Trimethylamine Oxide in Fish Muscle", Jl. Sc. Food Agric., 10, June, 1959

(75) Can Manufacturers Institute, Inc., "Test Procedures for Determining the Approximate Amount of Extractables from Coated Food and Beverage Containers and Closures," Aug., 1960

(76) CAREY, L. C., "Containers in Common Use for Fresh Fruits and Vegetables", USDA, Farmers' Bulletin 2013, Feb., 1950

(77) CAREY, L. C.; FOELSCH, G. G.; and STOKES, D. R., "Whys and Hows of Modern Packaging", Marketing - The Yearbook of Agric., USDA, 1954

(78) CARLE, L. A., "Keeping Quality of Chilled Dungeness Crab Meat Packed in Hermetically-Sealed Containers", Commercial Fisheries Review, 16, 11, Part I, and 17, 2, Part II

(79) CARROLL, J. G.; and BOLT, R. O., "Radiation Effects on Organic Materials", Nucleonics, 18, 9, Sept., 1960

(80) CHANG, P. Y.; YOUATHAN, M. T.; and WATTS, B. M., "Lipid Oxidation in Pre-Cooked Beef Preserved by Refrigeration, Freezing, and Irradiation", Food Tech., 15, 3, March, 1961

(81) CHARLESBY, A., "Atomic Radiation and Polymers", Pergamon Press, New York, N. Y., 1960

(82) CHARLEY, V. L. S., "The Prevention of Microbiological Spoilage in Fresh Fruit", Jl. Sc. of Food and Agric., July, 1959

(83) CHARM, S. E.; GOLDBLITH, S. A.; and PROCTOR, B. E., "Theoretical Considerations in Food Processing by Gamma Radiations - II A Simplified Mathematical Procedure for Evaluating Gamma Radiation Processes Inside Hallow Cylinder Sources", Food Tech., 12, 5, May, 1958

(84) CHRISTENSEN, C. J.; JACOBSEN, A. T.; KLINGER, Q.; and EVANS, M. D., "Dugway Cobalt-60 Irradiation Facility", Tech. Rpt., Da-18-108-CML-5347, Jan., 1959

(85) CLARKE, I. D., "Possible Applications of Ionizing Radiations in the Fruit, Vegetable and Related Industries", International Jl. of Applied Radiation & Isotopes, 6, Oct., 1959

(86) CLAYPOOL, L. L.; and DAVIS, L. D., "The Effect of Cold and Modified Atmosphere Storage on the Canning Quality of Cling Peaches", Food Tech., 13, 3, March, 1959

(87) COLEBY, B.; HORNE, T.; INGRAM, M.; and JEFFERSON, S., "Radiation Processing of Foods in Britain", Nucleonics, Nov., 1958

(88) COLLIER, J. E., "Citrus Fruits, Grapes, Berries, and Nuts: 1954", U. S. Dept. of Commerce, Bureau of Census, 1954

(89) COLLINS, C. G.; and CALKINS, V. P., "Radiation Damage to Elastomers, Plastics, and Organic Liquids", APEX-261, TID-4500 (11th Edition), Sept., 1956

(90) COLLINS, H. E., "Design of Containers for Irradiated Foods", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, July, 1959

(91) COMIN, D., "Successful Storage of Peaches Depends on Maturity and Post-Ripening", Ohio Farm and Home Research, July-Aug., 1955

(92) Consumer Union, "Frozen Fried Fish Sticks", Consumer Rpts., Feb., 1961

(93) CORNISH, E. H.; and SCI., M., "The Resistance of Coloured Polythene to Irradiation", Plastics, 25, 278, Dec., 1960

(94) CRAIN, R. C., "Testing Irradiated Food Packaging Papers", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., June, 1958

(95) CREAN, L. E.; ISAACS, P. J.; WEISS, G. J.; and FAHNOE, F., "Application of Isotopic Sources To Food and Drug Sterilization", Nucleonics, 11, 12, Dec., 1953

(96) CROPPER, W. H., "Radiation-Induced Coloration in Glass", SCR-79 (Reprint) Aug., 1959

(97) DASSOW, J. A.; POTTINGER, S. R.; and HOLSTON, J., "Preparation, Freezing, and Cold Storage of Fish, Shellfish, and Precooked Fishery Products", U. S. Dept. of Interior, Fishery Leaflet 430, Part 4, 1956

(98) DAVIS, T. F., "Radiosterilization of Edible Fish, Mollusks and Crustaceans", USAEC, Office of Tech. Inf., TID-3565, Aug., 1961

(99) DEES, L. T., "A List of the Fishery Bulletins of the United States Fish and Wildlife Service", U.S. Dept. of Interior, Fishery Leaflet 509, March, 1961

(100) DEMOISE, C. F.; and MILLER, E. V., "Effect of Low Temperatures on the Physiology of Grapefruit (Citrus Paradisi MacFad.)", Notes and Letters, 24, 3, May-June, 1959

(101) DENNY, C. F.; BOHRER, C. W.; PERKINS, W. E.; and TOWNSEND, C. T., "Destruction of Clostridium Botulinum by Ionizing Radiation", Food Radiation, 24, 1, Jan.-Feb., 1959

(102) DESROSIER, N. W.; and ROSENSTOCK, H. M., "Radiation Effects on Packaging Materials", Radiation Tech. in Food, Agric. and Biology, AVI Publ. Co., Inc., 1960

(103) DESROSIER, N. W., "The Refrigerated Storage of Perishable Commodities", The Tech. of Food Preservation, AVI Publ. Co.. Inc., 1959

(104) DESROSIER, N. W., "Preservation of Food with Ionizing Radiations", The Tech. of Food Preservation, AVI Publ. Co., Inc., 1959

(105) DIENES, G. J. "Radiation Effects in Solids", Annual Review of Nuclear Sc., 11, 1953

(106) DUGGAN, D. E.; ANDERSON, A. W.; and ELLIKER, P. R., "Ultraviolet Exposure Studies on a Gamma Radiation Resistant Micrococcus Isolated From Food", Radiation Preservation of Food, 24, 4, July-Aug., 1959

(107) DUNCAN, D. T.; HOOKER, W. J.; and HEILIGMAN, F., "Storage Rot Susceptibility of Potato Tubers Exposed to Minimum Sprout Inhibiting Levels of Ionizing Radiation", Food Tech., 13, 3, March, 1959

(108) DURAN, R.; and NORMAN, S. M., "Differential Sensitivity to Biphenyl Among Strains of Penicillium Digitatum Sacc.", Plant Disease Reporter, 45, 6, June, 1961

(109) EMERY, D. F.; and ANDREWS, J. S., "Food Irradiation", General Mills Research Bulletin, Progress thru Research, 1956

(110) ENGER, M. R.; and BREAKIRON, P. L., "Efficiency and Potential Economies of Dual-Purpose Shipping Containers for Mature-Green Tomatoes", USDA, Marketing Research Rpt. #257, July, 1958

(111) EUKEL, W. W.; and HUBER, W., "Tooling Up for Low Dose Irradiation Processing of Fresh Foods", Food Tech., 14, 4, April, 1960

(112) FAGERSON, I. S., "Effect of Irradiation on Pigmented Foods Used in Rations for the Armed Forces", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., May, 1956

(113) FARBER, L. ; and LERKE, P. A., "A Review of the Value of Volatile Reducing Substances for the Chemical Assessment of the Freshness of Fish and Fish Products", Food Tech., Dec., 1958

(114) FARBER, L.; and LERKE, P., "Studies on the Evaluation of Freshness and on the Estimation of the Storage Life of Raw Fishery Products", Food Tech., 15, 4, April, 1961

(115) FEAZEL, C. E.; BURKS, R. E.; MOSES, B.; and TRIPP, G. E., "Testing Packages for Irradiated Foods". Packaging Engin., 5, 4, April, 1960

(116) FEAZEL, C. E.; BURKS, R. E.; MOSES, B. C.; AND TRIPP, G. E., "Shed New Light on Stress Cracking", Package Engineering, 7, 2, Feb. 1962

(117) FEAZEL, C. E., "Determination of Effect of Packaging Materials on the Properties of Irradiated Foods", U. S. Army, Quartermaster Corps., Project # 7-84-01-002, Final Rpt., March, 1958

(118) FEAZEL, C. E.; MOSES, B. C.; BURKS, R. E., et al, "A Study of Irradiation in Combination with Model Food Systems on the Functional Properties of Food Containers", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #10, March, 1958

(119) FARRALL, A. W., "Five Year's Use of the 1,000,000 Volt Electron Beam Machine", Michigan State University, Sept., 1961

(120) Federal Register, "Resinous and Polymeric Coatings", Reg. 121.2514, Aug., 1961

(121) Federal Register, "Resinous and Polymeric Coatings for Paper and Paperboard", Reg. 121.2526, Dec., 1961

(122) FIELDS, M. L.; AMMERMAN, G. R.; and DESROSIER, N. W., "A Study of the Growth of Aspergillus Oryzae In Irradiated Components of Foods", Food Tech., Aug., 1960

(123) FINN, D. B., "Fish the Great Potential Food Supply", Food & Agric. Organization of the UN, World Food Problems, #3, Rome, 1960

(124) FRANCIS, F. J., "Determination of Pigment Changes Occurring In Irradiated Plant Products During Post-Irradiation Storage", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., Sept., 1957

(125) FUKADA, E.; STEPHENS, R. W. B.; CHARLESBY, A., "Dynamic Mechanical Properties of Irradiated High Density Polyethylene", Physics and Chemistry of Solids, 16, 1/2, Pergamon Press, Nov., 1960

(126) FUTRELL, G.; and KOLMER, L., "Consumer Marketing Handbook, III Fruits and Vegetables", Iowa State University of Sc. and Tech., May, 1961

(127) GALANTER, L.; RIZZO, F.; KUHL, O. A.; MANOWITZ, B.; and QUADRADO, A., "Theoretical and Experimental Study of Cesium-137 Irradiator Systems", Amer. Nuclear Soc., 1960 Annual Meeting, 3, 1, June, 1960

(128) GARTNER, J.; and KOLMER, L., "Consumer Marketing Bulletin", II. Economic Information for Consumer Marketing Programs, Iowa State Univ. of Sc. & Tech., May, 1961

(129) GERNON, G. D., "Ray-Pasteurizing of Produce Will Come First", Food Engin., May, 1959

(130) GINN, J. L., "Progress in Pre-Packaging Firm Ripe Peaches", USDA, Peach Growers Meeting, Jan., 1958

(131) GINN, J. L., "Pre-Packaging Firm Ripe Peaches", USDA, AMS-312, June, 1959

(132) GLASS, R. A.; and SMITH, H. D., "Radioactive Isomer Production in Foods by Gamma Rays and X-Rays", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Final Rpt., June, 1960

(133) GLASS, R. A.; and SMITH, H. D., "Radioactivities Produced in Foods by High-Energy Electrons", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #10, Dec., 1959

(134) GODWIN, M. R., "Consumer Packaging as a Method of Retailing Fruits & Vegetables Produced in the N. E.", Part I. Consumer Acceptance & Retailing Losses, Cornell Univ. Agri. Experimenta Station, Bulletin 870, July, 1951

(135) GODWIN, M. R., "Consumer Packaging as a Method of Retailing Fruits and Vegetables Produced in the N. E.", Part II. Labor Requirements, Packaging Costs etc., Cornell Univ. Agri. Experiment Station, A.E. 829, July, 1952

(136) GOLDBERG, A. J., "Wholesale Prices and Price Indexes - 1959", U. S. Dept. of Labor, Bureau of Labor Statistics, Bulletin #1295, June, 1961

(137) GOLDBLITH, S. A.; and PROCTOR, B. E., "Evaluation of Food Sterilization Efficiency", Nucleonics, 10, 9, Sept., 1952

(138) GOLDBLITH, S. A.; and PROCTOR, B. E., "Relative Merits of Cathode Rays and Gamma Radiations", Nucleonics, 12, 2, Feb., 1954

(139) GRONBECH, G., "Consumption Trends and Patterns for Vegetables, Potatoes, Sweetpotatoes, and Dry Beans and Peas", USDA, Agric. Handbook, #215, July, 1961

(140) GRONINGER, H. S., "Formation of Acetoin in Cod and Other Bottom-Fish Fillets During Refrigerated Storage", Food Tech., Jan., 1961

(141) GUADAGNI, D. G.; DOWNES, N. J.; SANSHUCK, D. W.; and SHINODA, S., "Effect of Temperature on Stability of Commercially Frozen Bulk Pack Fruits-Strawberries, Raspberries, and Blackberries", Food Tech., 15, 4, April, 1961

(142) GUILFOY, R. F.; and JOHNSON, H. D., "Suggested Methods for Checking Temperatures of Fresh and Frozen Food Shipments", USDA, Marketing Research Rpt., #150, Dec., 1956

(143) GUNTHER, F. A.; BLINN, R. C.; BARKLEY, J. H.; and KOLBEZEN, M. J., "Fungicides for Package Foods, Generation of Ammonia for In-Package Fumigation of Foodstuffs", Jl. of Agric. and Food Chemistry, 7, 7, July, 1959

(144) GUNTHER, F. A.; BLINN, R. C.; KOLBEZEN, M. J., et al, "Sorption of Ammonia by Fruits, Vegetables, Eggs, and Fiberboard in Dynamic Systems", Jl. of Agric. and Food Chemistry, 7, 7, July, 1959

(145) HALE, P. W.; STOKES, D. R., "Pre-Packaging California Grapes at Shipping Point", USDA, Marketing Research Rpt. #410, July, 1960

(146) HALLER, M. H., "Handling, Transportation, Storage, and Marketing of Peaches", USDA, Bibliographical Bulletin #21, Dec., 1952

(147) HALLER, M. H.; HARDING, P. L.; and LUTZ, J. M., "Respiration of Citrus Fruits After Harvest", Jl. of Agric. Research, 71, 8, Oct., 1945

(148) HALLER, M. H.; HARDING, P. L.; LUTZ, J. M.; and ROSE, D. H., "The Respiration of Some Fruits in Relation to Temperature, American Soc. for Hort. Sc., 1931

(149) HALSEY, L. H.; MCCOLLOCH, L. P.; and SPURLOCK, A. H., "Containers for Shipping Florida Tomatoes", Univ. of Fla., Agric. Experiment Sta. Bulletin 560, April, 1955

(150) HANNAN, R. S., "The Preservation of Food With Ionizing Radiations", Food Sc. Abstracts, 26, 2, 1954

(151) HANNAN, R. S., "Research on the Science and Technology of Food Preservation by Ionizing Radiations", Chemical Publ. Co., Inc., 1956

(152) HANNAN, R. S., "Low Temperature Research Station Radiation Group", L.T.R.S. Record Memorandum 314, Oct., 1955 - Dec., 1957

(153) HARDENBURG, R. E., "What Values Accrue From Pre-Packaging Fresh Produce", USDA, AMS, July, 1961

(154) HARDENBURG, R. E., "Polyethylene Box Liners for Storage of Golden Delicious Apples", USDA, Marketing Research Rpt. #461, March, 1961

(155) HARDENBURG, R. E.; SCHOMER, H. A.; and UOTA, M., "Polyethylene Film for Fruit", Modern Packaging, 31, 6, Feb., 1958

(156) HARDENBURG, R. E.,"How to Ventilate Packaged Produce", Pre-Pack-Age, 7, 6, Feb., 1954

(157) HARDENBRUG, R. E., "Basic Facts on Maintaining FRESHNESS in Produce", Pre-Pack-Age, 10, 8, May, 1957

(158) HARDENBURG, R. E., "Value of Produce Pre-Packaging", Amer. Paper Merchant, 51, 4, April, 1954

(159) HARDENBURG, R. E., "How to Get the Most from a Package", Market Growers Jl., Aug., 1952

(160) HARDING, P. L.; WIANT, J. S.; and HRUSCHKA, H. W., "The Effect of Pre-Storage Packinghouse Treatments on the Control of Decay of Florida Oranges During Storage At Orlando, Florida & New York City, 1951", USDA, AMS-233, April, 1958

(161) HARDING, P. L.; LUTZ, J. M.; RADSPINNER, W. A.; and SUNDAY, M. B., "Influence of Chemical Treatments & Polyethylene Bags on Keeping Quality of Florida Grapefruit, USDA, AMS-8, Jan., 1955

(162) HARRINGTON, R.; and GIBERSON, R., "Chemical and Physical Changes in Gamma-Irradiated Plastics", Modern Plastics, Nov., 1958

(163) HARVEY, E. M.; ATROPS, E. P.; RADSPINNER, W. A.; LUTZ, J. M., et. al "A Comparison of Types of Containers, Refrigeration, & Loads in the Cartons from Central Calif. to Chicago & New York Dec., 1952 & Jan., 1953", USDA, AMS-135, Aug., 1956

(164) HARVEY, J. M.; and PENTZER, W. T., "Market Diseases of Grapes and Other Small Fruits", USDA, Agric. Handbook #189, Nov., 1960

(165) HARVEY, E. M.; and ATROPS, E. P., "Storage Tests With Lemons in Non-Ventilated Cartons with and Without Biphenyl and with & Without 2, 4-D Water Wax Prestorage Treatment Dec., 1952 to Aug., 1953", USDA, H.T.&S. Office Rpt. #296, Aug., 1953

(166) HATHAWAY, C. T., "Evaluation of Films for Irradiation Packaging of Foods", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #5, Jan., 1959

(167) HAVAS, N.; HENDERSON, P. L.; PARSONS, C. S.; and SCHAFFER, P., "Displaying Fruit in Various Types of Packages and in Bulk", (Costs and Effects on Quality and Sales), USDA, AMS, Aug., 1960

(168) HAWES, R. L.; MCGAHA, M. E.; and STOKES, D. R., "Pre-Packaging Thompson Seedless Grapes in Cellophane Bags in Retail Stores", USDA, Jan., 1953

(169) HEDIN, P. A.; KURTZ, G. W.; and KOCH, R. B., "Production and Prevention of Irradiated Odor in Beef", Chemistry and Biochemistry of Food," 25, 3, May-June, 1960

(170) HEERDT, M., "Wrapping Materials for Frozen Fish", USDI, Fishery Leaflet 213, Jan., 1947

(171) HEERDT, M. B.; BUCHER, D. L.; and STANSBY, M. E., "Refrigerated Locker Storage of Fish and Shellfish", USDI, Fishery Leaflet 128, June, 1949

(172) HEFLIN, L., "Fresh Fruit and Vegetable Prices 1960, USDA, Statistical Bulletin #285, May, 1961

(173) HEINEN, J. M.; DAVIS, R. B.; and DOWLING, J. E., "Radiation Sterilization of Canned Foods", U. S. Army, Quartermaster Corps., Project #7184-01-002, Final Rpt., Oct., 1956

(174) HEINEN, J. M.; FOLINAZZO, J. F.; NANK, W. K.; and SCHMIDT, C. F., "Comparative Resistance of Strains of Clostridium Botulinum to Ionizing Radiation", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt., #1, Sept., 1958

(175) HENDERSON, J. M.; and LINNENBERG, C. C., "Shifts in Rail and Truck Transportation of Fresh Fruits and Vegetables", USDA, Marketing Research Rpt. 237, June, 1958

(176) HETZEL, W. G.; "Containers for Fresh Fruits and Vegetables Published in Four Container Tariffs", National Container Committee, April, 1961

(177) HORROCKS, L. A., "How Radiation Affects Six Organic Coatings", Materials in Design Engin., Jan., 1958

(178) HORTON, R. E., "Endless Conveyor Table Improves Fish Fillet Packaging", Package Engin., Dec., 1959

(179) HRUSCHKA, H. W.; and KAUFMAN, J., "Films for Lemons, Modern Packaging, May, 1952

(180) HRUSCHKA, H. W., "Polyethylene for Citrus", Modern Packaging, Feb., 1954

(181) HUBER, W.; and KLEIN, A. S., "Cuts Food Radiation Costs", Food Engin., Jan., 1960

(182) JENSEN, B. C., "Studies to Determine Optimum Characteristics of In-Package Active Carbons for Removal of Irradiated Flavor During Storage", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #1, Aug., 1958

(183) JOHNSON, H.; and BREAKIRON, P. L., "Protecting Perishable Foods During Transportation by Truck", USDA, Handbook #105, Dec., 1956

(184) JOHNSON, H. D.; GERRITY, M. V.; and GARVER, C. E., "Transportation Tests of Fresh Meat and Packinghouse Products in Refrigerator Cars", USDA AMS-17, March, 1955

(185) JONES, N. R., "Browning Reactions & The Loss of Free Amino Acid and Sugar From Lyophilized Muscle Extractives of Fresh & Chill-Stored Codling (Gadus Callarias)," Biochemical & Chemical Res. on Food, 24, 6, Nov.-Dec., 1959

(186) JONES, N. R., "The Free Amino-Acids of Fish. II-Fresh Skeletal Muscle from Lemon Sold (Pleuronectes Microcephalus), Jl. Sc. of Food Agric., May, 1959

(187) KAREL, M.; PROCTOR, B. E.; and WISEMAN, G., "Factors Affecting Water-Vapor Transfer Through Food Packaging Films", Food Tech., 13, 1, Jan., 1959

(188) KARPOV, V. L.; MALINSKY, Y. M.; and SERENKOV, V. I., "Radiation Makes Better Woods and Copolymers", Nucleonics, 18, 3, March, 1960

(189) KAUFMAN, J.; HARDENBURG, R. E.; and LUTZ, J. M., "Weight Losses & Decay of Fla. & Calif. Oranges in Mesh s & Perforated Polyethylene Consumer Bags" Amer. Soc. for Hort. Sc., 67, 1956

(190) KECK, F. L., "Effects of Beta Irradiation on a Typical Metal Finish", Official Digest, Sept., 1958

(191) KEMPE, L. L.; GRAIKOSKI, J. T.; and BROWNELL, L. E., "Ray-Sterilizing Food Wrappers", Food Engin., Nov., 1953

(192) KEMPE, L. L.; BONVENTRE, P. F.; and GRIAKOSKI, J. T., "Bacteriological Aspects of Ionizing Radiation in Food Processing", TID-7512, Conf. on Radioactive Isotopes in Agric. Michigan S. Univ., Jan., 1956

(193) KERTESZ, Z. I., "A Study of the Radiation-Induced Softening of Plant Tissues", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Jan., 1959

(194) KINSMAN, S.; ANDERSON, F. D.; CLEVELAND, R. S.; HARLESS, B. L.; and HENKE, C. F., "Radiological Health Handbook", U. S. Dept. of Health, Ed. & Welfare, PB-121784, Jan., 1957

(195) KLINE, E. F.; ABBEY, A.; FIRMAN, M. C.; and HOPPER, P. F., "Thermal and Nonthermal Degradation of Acronize Chlortetracycline in Fish and Some Shellfish, Food Tech., June, 1960

(196) KILS, J. B.; WITTER, L. D.; and ORDAL, Z. J., "The Effect of Several Antifungal Antibiotics on the Growth of Common Food Spoilage Fungi", Food Tech., 13, 2, Feb., 1959

(197) KRASNANSKY, V. J., "Properties of Irradiated Non-Metallic Packaging Materials", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #6358, April, 1959

(198) KRAYBILL, H. F., "Current Status of Applications in the Pasteurization or Sterilization of Foods by Ionizing Radiations", 2nd Annual Texas Conf. on Utilization of Atomic Energy, E-72-60, Nov., 1959

(199) KRAYBILL, H. F.; and BRUNTON, D. C., "Commercialization Technology and Economics in Radiation Processing", Agric. and Food Chemistry, 8, 5, Sept.-Oct., 1960

(200) LARSEN, S. A., "Packaging Research: An Inventory", American Management Assoc. Inc., Research Study No. 37,1957

(201) LARSON, W. S., "Investigation of Containers for Radiation Preservation of Food", U. S. Army Quartermaster Corps, Project No. 7-84-01-002, Final Report, Dec., 1959

(202) LAUDANI, H.; DAVIS, D. F.; and SWANK, G. R., "Improved Packaging Can Cut Insect Infestation", Agricultural Marketing, March, 1959

(203) LAUGHLIN, H. F., " Studies to Determine Optimum Characteristics of In-Package Active Carbons for Removal of "Irradiation Flavor" During Storage," U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Report #3, Dec., 1958

(204) LAWTON, E. J.; BELLAMY, W. D.; HUNGATE, R. E.; BRYANT, M. P.; and HALL, E., " Some Effects of High Velocity Electrons on Wood", Science, 113, #2936. April, 1951

(205) LEA, C. H.; MAC FARLANE, J. J.; and PARR, L. J., "Treatment of Meats with Ionizing Radiations, V. Radiation Pasteurization of Beef for Chilled Storage", J. of the Science of Food and Agribulture, 11, Dec., 1960

(206) LECLAIR, H. C.; and COBBS, W. H., Jr., "Effects of Radiation on Plastic Packaging Films", Industrial & Engineering Chemistry 50, March, 1958

(207) LERKE, P. A.; FARBER, L.; and HUBER, W., " Preservation of Fish and Shellfish by Relatively Low Doses of Beta Radiation and Antibiotics", Food Technology, 15, 3, March, 1961

(208) LEWIS, W. E., "The Shelf Life of Florida Valencia Oranges in Retail Store Display Cases", U. S. Dept. of Agriculture, H. T. & S. Office Rpt. #301, August, 1953

(209) LEWIS, W. E., "Maintaining Produce Quality in Retail Stores", U. S. Dept. of Agriculture, Agriculture Handbook No. 117, March, 1957

(210) LEWIS, W. E., "Temperatures of Produce in Retail-Store Type Display Cases", U. S. Dept. of Agriculture, AMS-69, Sept., 1955

(211) LEWIS, W. E., " The Shelf Life of Fresh Fruits and Vegetables in Retail Store Display Cases", U. S. Dept. of Agriculture, H. T. & S. Office Report #247, Oct., 1951

(212) LEWIS, W. E., "The Shelf Life of Lemons in Retail Store Display Cases", U. S. Dept. of Agriculture, H. T. & S., Office Report #294, April, 1953

(213) LEWIS, W. E., "The Shelf Life of Tangerines in Retail Store Display Cases", U. S. Dept. of Agriculture, H. T. & S., Office Report #278, Aug., 1952

(214) LISTON, J.; CHAPE, J. G.; and STERN, J. A., " The Spoilage of Pacific Coast Rockfish I. Spoilage in Ice Storage", Food Technology, Jan., 1961

(215) LITTLE, A. D., Inc., " Radiation A Tool for Industry", ALI-52, Jan., 1959

(216) LOVERN, J. A.; OLLEY, J.; and WATSON, H. A., " Changes in the Lipids of Cod During Storage in Ice", J. of Science Food Agric. 10, June, 1959

(217) LUKTON, A.; and MACKINNEY, G., "Effects of Ionizing Radiations on Carotenoid Stability", Food Technology, 1956, 10, 12, 1956

(218) LUTZ, J. M.: and WILCOX, . M. S., "Packaging Quality Maintenance and Improvement Section;" U. S. Dept. of Agriculture, Market Quality Research Division, Feb., 1960

(219) MACLEAN, D. P.; and WELANDER, C., " The Preservation of Fish with Ionizing Radiation: Bacterial Studies", Food Tech., May, 1960

(220) MACLEOD, R. A.; JONAS, E. E.; and MCBRIDE, J. R., "Sodium Ion, Potassium Ion, and Weight Changes in Fish Held in Refrigerated Sea Water and Other Solutions", Agricultural and Food Chemistry, 8, 2, March-April, 1960

(221) MACLINN, W. A., "Commodity Storage Manual", Refrigeration Research Foundation, Copyright, 1957

(222) MANCHESTER, A. C., "Orange Tree to Breakfast Table", U. S. Dept. of Agriculture, MRR #164, June, 1957

(223) MANOWITZ, B.; KUHL, O. A.; GALANTE, L.; BRETTON, R. H.; and ZWICKLER, S., " Experimental Parametric Study of Large-Scale Co^{60}, NA^{24}, and CS^{137} Slab Irradiators", Large Radiation Sources in Industry, International Atomic Energy Agency, 1, 1960

(224) MANYPENNY, G. O., " Glossary of Packaging Terms", Packaging Institute, Inc., 1955

(225) MARKAKIS, P.; LIVINGSTON, G. E.; and FAGERSON, I. S., "Effects of Cathode Ray and Gamma Ray Irradiation on the Anthocyanin Pigments of Strawberries", Radiation Preservation of Food, 24, 5, Sept.-Oct., 1959

(226) MARTIN, D. C., "Effect of Ionizing Radiation on the Storage Life and Quality of Certain Vegetables and Fruits," U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Report #3, Jan., 1959

(227) MARTIN, D. C., "The Extension of Storage Life of Fresh Fruits and Vegetables by Ionizing Radiation", U. S. Army, Quartermaster Corps, Project # 7-84-01-002, Rpt. #2, Oct., 1955

(228) MEHRLICH, F. P., "The Current Outlook for Radiation Processed Foods", Activities Rpt., 13, March, 1961

(229) MEHRLICH, F. P., "Progress is Being Made in Food Radiation", Food Processing, 22, 5, May, 1961

(230) MEHRLICH, F. P.; and LITTLEJOHN, J. P., "Radiation Preservation of Foods Project", U. S. Army, Quartermaster Corps, Project #7-84-01-002 Rpt. #14-16, June, 1961

(231) MIKE, T. M.; STEIERMAN, B. L.; and DEGERING, E. F., "Effects of Electron Bombardment on Properties of Various Glasses", Amer. Ceramic Soc. Symposium on Radiation Effects, Oct., 1959

(232) MILLER, E. V.; and GLASS, C. S., "Observations on the Regreening of Late Varieties of Oranges", Notes and Letters, 22, 6, Nov.-Dec., 1957

(233) MILLER, S. A.; LICCIARDELLO, J. J.; NICKERSON, J. T. R.; and GOLDBLITH, S. A., "A Literature Survey on the Effects of Ionizing Radiations on Sea Foods With Respect to Wholesomeness Aspects", US, AEC, Rpt. #9656, TID-11610-1959

(234) MITCHELL, G. H.; and SHERMAN, R. W., "History of Pre-Packaging Fresh Fruits and Vegetables", USDA, Economics & Rural Sociology, Mimeograph # AE-254, June, 1955

(235) MIYAUCHI, D. T., "Irradiation Preservation of Pacific Northwest Fish. I. Cod Fillets", Food Tech., Aug., 1960

(236) Modern Packaging Encyclopedia for 1961/November, 1960, 34, 3A, 1961

(237) MOORJANI, M. N.; IYENGAR, J. R.; VISWESWARIAH, K. et al, "Changes in the Total Volatile Base, Volatile Reducing Substances and Bacterial Count as Indices of Fresh Water Fish Spoilage", Food Tech., Aug., 1958

(238) MORGAN, B. H., "Radiation Chemistry of Foods - 1958", 2nd. U. N. Inter. Conf. on Peaceful Uses of Atomic Energy, Aug., 1958

(239) MORGAN, B. H., "Current Status of Radiation Preservation of Foods: Part II", Food Processing, July, 1957

(240) MORGAN, B. H.; and SIU, R. G. H., "Action of Ionizing Radiations on Individual Foods", Radiation Preservation of Food, U. S Army, Quartermaster Corps., Aug, 1957

(241) MORRISON, W. W., "Preparing Peaches for Market", USDA, Marketing Bulletin #9, Aug., 1960

(242) MORRISON, W. W., "Preparing Strawberries for Market", USDA, Farmers' Bulletin #1560, Nov, 1959

(243) MOTTS, G. N., "Marketing Handbook for Michigan Fruits and Vegetables", Agric. Experiment Station, Michigan State Univ., Bulletin #418, Dec., 1957

(244) MULLINS, W. R.; and BURR, H. K., "Treatment of Onions with Gamma Rays: Effects of Delay Between Harvest and Irradiation", Food Tech., 15, 4, 1961

(245) MCARDLE, F. J; and NEHEMIAS, J. V. "Effect of y-Radiation on the Pectic Constituents of Fruits and Vegetables", Food Tech., 10,-12, 1956

(246) MCBRIAN, R., "Use of Ionizing Radiations to Preserve Fruits and Vegetables, U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #1, Feb., 1960

(247) MCBRIAN, R., "Use of Ionizing Radiations to Preserve Fruits and Vegetables," U. S. Army, Quartermaster Corps., Project #-7-84-01-002, Rpt. #5, Aug., 1959

(248) MCKERNAN, D. L., "Hearings Before the Subcommittee on Research & Development on the Joint Committee on A. E. Congress of the U. S. Part II.", National Food Irradiation Research Program, March, 1960

(249) MCKERNAN, D. L., Bureau of Commercial Fisheries "Operations of the Bureau of Commercial Fisheries Under the Saltonstall-Kennedy Act, Fiscal Year 1959", USDI, C.F.S., No. 2578, 1959

(250) National Research Council, "Food-Packaging Materials Their Composition and Uses", NAS-National Research Council, Publication 645, Washington 25, D.C., Nov. 1958

(251) NELSON, K. E.; MAXIE, E. C.; and EUKEL, W., "Some Studies in the Use of Ionizing Radiation to Control Botrytis Rot in Table Grapes and Strawberries", Phytopathology, 49, Aug. 1959

(252) NEWHALL, W. F.; and GRIERSON, W., "A Low Cost, Self-Polishing, Fungicidal Water Wax for Citrus Fruit", Citrus Magazine, March 1956

(253) NICHOLAS, R. C; and WIANT, D. E., "Radiation of Important Grain-Infesting Pests; Order of Death Curves, and Survival Values for the Various Metamorphi Forms", Food Tech., 13, 1, Jan., 1959

(254) NICHOLSON, P. A., "Changes in Citrus Fruit Marketing", USDA, Annual Meeting of Texas Citrus Mutual, AMS, June, 1961

(255) NICKERSON, J. T. R; LOCKHART, E. E.; and PROCTOR, B. E., "Ionizing Radiations for the Control of Fish Spoilage", Food Tech. 8, 1, Jan., 1954

(256) NICKERSON, J. T. R; GOLDBLITH, S. A.; MILLER, S. A., et al, "Outline of Projects to Determine the Feasibility of Radiation Preservation of Marine Products", USAEC, TID-6700, April, 1961

(257) NIGHTINGALE, F. S.; and BUNTIN, J. L., "Fresh Fruit and Vegetable Shipments(by Commodities, States, Months)", USDA, AMS-36 (1960), May, 1961

(258) NIGHTINGALE, F. S.; and BUNTIN, J. L., "Fresh Fruit and Vegetable Unload Totals in 100 Cities", USDA, AMS-25 (1960), April, 1961

(259) NIGHTINGALE, F. S.; and BUNTIN, J. L., "Fresh Fruit and Vegetable Unloads in Eastern Cities by Commodities, States and Months", USDA, AMS-427, July, 1961

(260) O'BRIEN, J. J., "New England Fisheries-- Annual Summary, 1960", USDI, A48: 923, 1960

(261) O'BRIEN, R., "Investigation of the Effects of Irradiation on Foods Packaged in Hermetically Sealed Aluminum Foil Containers", U. S. Army, Quartermaster Corps, Project # 7-84-01-002, Report #1, Aug., 1958

(262) ORR, M. L.; and WATT, B. K., "Amino Acid Content of Foods", USDA, Home Economics Res. Rpt. #4, Dec., 1957

(263) PAWSKI, L.; and FINDLEN, H., "Handling and Shipping Potatoes to Processing Plants in Pallet Boxes and Burlap Bags", USDA, MRR No. 495, Sept., 1961

(264) PEARSON, A. M.; COSTILOW, R. N; BATZER, O. F., "The Relationship Between Panel Scores and Certain Chemical Components in Precooked Irradiated Meats", Food Research, 24, 2, March-April, 1959

(265) PECKNER, D., "Radiation Damage in Metals", Engineering and Design, Jan., 1960

(266) PECOT, R. K.; and WATT, B. K., "Food Yields-Summarized by Different Stages of Preparation", USDA, Agriculture Handbook #102, June, 1956

(267) PENDERGAST, H. E.; and HOFFMAN, A. S., "Tensile, Impact and Dielectric Properties of Irradiated Polymers", AIEE, No. CP-61-391, Feb., 1961

(268) PENTZER, W. T., "Storage of Agricultural Raw Products", Handbook of Food and Agriculture, Reinhold Publishing Corp., 1955

(269) PENTZER, W. T., "Waste and Spoilage", USDA, Marketing, The Yearbook of Agriculture, 1954

(270) PETERS, J. A., "Review of Problems in Handling and Packaging Chilled Fishery Products", Fishing Gazette, MS. G-71, Annual Review Number, 1961

(271) PHILLIPS, A. W., "The Chemical Enhancement of Bacterial Radio-Sensitivity in the Radiation Sterilization of Foods", US. Army, Quartermaster Corps, Project No. 7-84-01-002, Final Report, Dec., 1959

(272) PHILLIPS, A. W; NEWCOMB, H. R.; ROBINSON, T; and BACH, F., "Experimental Preservation of Fresh Beef with Antibiotics and Radiation", Food Tech., Jan., 1961

(273) PODANY, J. C., "Costs of Packing California Peaches in 1959", USDA, MRR#443, Dec., 1960

(274) POWELL, J. V., "Costs of Packing Colorado Peaches in 1956", USDA, AMS, MRR #179, July, 1957

(275) POWELL, L. A.; and GODWIN, M. R., "Economic Relationships Involved in Retailing Citrus Products", Univ. of Florida, Agric. Experiments Sta., Bulletin 567, Aug., 1955

(276) POWER, E. A., "Fisheries of the United States and Alaska, 1958", USDI, Fishery Leaflet 393, Rev., March, 1959

(277) POWER, E. A., " Fisheries of the United States 1960- A Preliminary Review", USDI, Fishery Leaflet 393, April 1961

(278) POWER, E. A., "Fishery Statistics of the United States", USDI, Statistical Digest #44, 1957

(279) PRATT, G. B.; and WILBUR, A. C., "Corrosion Studies of Irradiated Canned Food", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Annual Report #5, Sept., 1960

(280) PRATT, G. B.; WHEATON, E.; BOHRER, C. W.; and DENNY, C. B., "Destruction of Clostridium Botulinum by Ionizing Radiation Part II., Peas, Chicken, Soup, and Pork in the Frozen State", Food Radiation, 24, 1, Jan.-Feb., 1959

(281) PRATT, G. B., "Research Study on Can Enamels as Part of the Radiation Preservation of Foods Program", U. S. Army, Quartermaster Corps, Project # 7-84-01-002, Final Report, May, 1960

(282) PROCTOR, B. E., "Cathode-ray Irradiation of Cellophanes", Modern Packaging, Jan., 1957

(283) PROCTOR, B. E., "Development of a Method of Radiation Sterilization of Foods Without Adverse Flavor and Chemical Changes", U. S. Army, Quartermaster Corps, Project # 7-84-01-002, Final Report, April, 1957

(284) PROCTOR, B. E.; GOLDBLITH, S.; NICKERSON, J. T. R.; and FARKAS, D. F., " Evaluation of the Technical, Economic and Practical Feasibility of Radiation Preservation of Fish", USAEC, NYO-9182, TaskVI, Contract#AT(30-1)2329, 1959

(285) PROCTOR, B. E.; NICKERSON, J. T. R.; LICCIARDELLO, J. J.; GOLDBLITH, S. A.; and LOCKHART, E. E., "Extension of Food Storage Life by Irradiation". MIT, Dept. of Food Tech., June, 1955

(286) PROCTOR, B. E, "Procurement of Services Pertinent to the Determination of Bacterial Resistance of Packages", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, March, 1958

(287) PROCTOR, B. E.; NICKERSON, J. T. R.; and GOLDBLITH, S. A., "Storage of Haddock", Refrigerating Engineering, April, 1950

(288) Produce Packaging Association, "Bibliography-Papers on Packaging Fresh Fruits and Vegetables- 1961", 1961

(289) PUBOLS, B. H., "A Quarter Century of Peaches", USDA, The Fruit Situation, TFS-139, June, 1961

(290) PUBOLS, B. H., "A Half Century of Fruit Consumption", USDA, The Fruit Situation, TFS-140, Aug., 1961

(291) RAMSEY, G. B.; SMITH, M. A., "Market Diseases Caused by Fungi", USDA, Plant Disease, The Yearbook of Agriculture, 1953

(292) RASMUSSEN, M. P.; and DOMINICK, B. A., "Prepackaging Fresh Fruits and Vegetables in the Northeast by Commercial Prepackers", Cornell University, A. E. 1097, April, 1958

(293) READ, M. S., "Current Aspects of the Wholesomesness of Irradiated Food", Engineers Joint Council, Nuclear Engineering & Science Conference, New York, April, 1960

(294) REARDON, C. M., "Seattle and Astoria Landings, Receipts, and Value of Fishery Products", USDI, Bureau of Commercial Fisheries, 1960

(295) REDIT, W. H.; and HAMER, A. A., "Protection of Rail Shipments of Fruits and Vegetables", USDA, Agriculture Handbook #195, July, 1961

(296) REDIT, W. H.; and HAMER, A. A., "Precooling and Shipping Louisiana Strawberries", USDA, MRR #358, 1959

(297) REESE, R. B., "Production of Frozen Prepared Foods- 1954-1955", USDA, Rpt. #170, May, 1957

(298) REEVE, R. M.; and NEUFELD, C. H. H., "Observations on the Histology and Texture of Elberta Peaches from Trees of High and Low Levels of Nitrogen Nutrition", Food Research, 24, 5, Sept.-Oct., 1959

(299) REINSMITH, G., "Nuclear Radiation Effects on Materials", ASTM Bulletin, (TP-185) Sept., 1958

(300) REYNOLDS, O. C., "Containers and Packaging-Industry Report", U. S. Dept. of Commerce, 14, 2, Summer-1961

(301) RICHARDSON, H. B., "28 lb. Cartons for California Emperor Grapes", The Blue Anchor, May, 1958

(302) RISOLI, T. J., "New York City's Wholesale Fishery Trade", USDI, A56: 875, 1960

(303) ROBERTSON, B. C., "List of Manufacturers of Packages, Packaging Materials and Equipment for Prepackaging Fresh Fruits & Vegetables", USDA, Production & Marketing Administration, May, 1951

(304) ROBERTSON, B. C., "Types and Sizes of Containers Used for Prepackaged Tomatoes", USDA, AMS-52, Aug., 1958

(305) ROCK, R. C.; and RIZZI, A. D., "The Where and When of California Fruit and Nut Crops", Calif. Agricultural Experiment Sta., Extension Service Manual 20, Dec., 1955

(306) ROMANI, R. J.; MAXIE, E. C.; and ROBINSON, B. J., "Radiation Preservation of Fresh Strawberries and Grapes", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, March, 1961

(307) ROSE, D. H.; and GORMAN, E. A., "Handling, Precooling, and Transportation of Florida Strawberries", USDA, Technical Bulletin #525, Oct., 1936

(308) ROSE, D. H.; COOK, H. T.; and REDIT, W. H., "Harvesting, Handling, and Transportation of Citrus Fruits", USDA, Bibliographical Bulletin No. 13, Jan., 1951

(309) ROYCE, W. F.; BULLER, R. J.; and PREMETZ, E. D., "Decline of the Yellowtail Flounder (Limanda Ferruginea) Off New England", USDI, Fish & Wildlife Service, 59, Fishery Bulletin 146, 1959

(310) RUMBERGER, G. G., "Effect of Ionizing Radiation on Materials for Carton Construction", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, Sept., 1960

(311) RYALL, A. L., "A Study of Packaging Materials", Ice and Refrigeration, Aug., 1952

(312) RYALL, A. L.; and HARVEY, J. M., "The Cold Storage of Vinifera Table Grapes", USDA, Agriculture Handbook,#159, June, 1959

(313) RYGG, G. L.; and HARVEY, E. M., " Storage Behavior of Lemons from the Desert Areas of Arizona and California", USDA, MRR #310, March, 1959

(314) SAINSBURY, G. F.; and SCHOMER, H. A., " Influence of Carton Stacking Patterns on Pear Cooling Rates", USDA, MRR #171, April, 1957

(315) SALUNKHE, D. K., "Gamma Radiation Effects on Fruits and Vegetables", Economic Botany, #15, 1961

(316) SALUNKHE, D. K.; POLLARD, L. H.; GERBER, R. K.; WILCOX, E. B.; and SIMON, M., " Packaging Effects on the Flavor and Shelf Life of Gamma-Irradiated Fresh Fruits and Vegetables", Package Engineering 4:2(1959)

(317) SALUNKHE, D. K., "Studies on Radiation Preservation of Fruit and Vegetable Products", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, Nov., 1959

(318) SAMSON, V. J., "California Fishery Market News Monthly Summary", USDI, M13,923, Feb., 1961

(319) SCATTERGOOD, L. W., "English Translations of Fishery Literature Additional Listings, 1957", USDI, Rpt. #227, Aug., 1957

(320) SCHMIDT, C. F.; and NANK, W. K., "Radiation Sterilization of Food. I. Procedures for the Evaluation of the Rad. Resistance of Spores of Clostridium Botulinum in Food Products", Food Research, 25, 3, May-June, 1960

(321) SCHMIDT, C. F.; LECHOWICH, R. V.; and FOLINAZZO, J. F., "Growth and Toxin by Type E Clostridium Botulinum Below 40°F.", Jl. of Food Sci., 26, 6, Nov.-Dec., 1961

(322) SCHOMER, H. A., "Reducing Mechanical Damage in Handling Apples", USDA, Biological Sciences Branch, AMS- 38253, pp. 60-65

(323) SCHOMER, H. A., "Polyethylene Film Bag Liners for Packaging Fresh Fruit", USDA, Biological Sciences Branch, AMS-38253, pp. 45-48

(324) SCHOMER, H. A., "Prepackaging as an Aid in Marketing Farm Products", Southern Assoc., of Science and Industry, Southwide Winter Meeting, New Orleans, Louisiana, Jan., 1950

(325) SCHOMER, H. A., "Refrigeration of Prepackaged Produce", Pre-Pack-Age, Nov., 1949

(326) SCHROEDER, W. T.; and PROVVIDENTI, R., "Tomato Fruit Disorders", Farm Research, June, 1961

(327) SCHULTZ, H. W., "Increasing the Acceptance of Irradiated Meat and Meat Products by Selected Treatments Before, During, and Following Irradiation", US. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, Dec., 1956

(328) SCHULTZ, H. W.; CAIN, R. F; BUBL, E. C; and NORDAN, H. C., "Effect of Ionizing Radiation on Acceptance of Foods", Supt. of Documents, U. S. Printing Office, Washington 25, D. C., TID-7512, Conference on Radioactive Isotopes in Agriculture, Jan, 1956

(329) SCOTT, L. E.; and TEWFIK, S., "Atmospheric Changes Occurring in Film-Wrapped Packages of Vegetables and Fruits", American Society for Horticultural Science, 49, 1947

(330) SCOTT, L. E.; and TEWFIK, S., "Atmospheric Conditions--In Consumer Packages of Vegetables", Pre-Pack-Age, Sept. 1947

(331) SEELIG, R. A., "Fresh Facts about the Fresh Fruit and Vegetable Industry", United Fresh Fruit and Vegetables Association, 3rd Edition, June, 1957

(332) SEITZ, F.; and KOEHLER, J. S., "Radiation Disarrangement of Crystals", Impurities and Imperfections, Amer. Society for Metals, 1955

(333) SELTZER, R. E., "Desert Grapefruit Goes to Market", U. of Arizona, Agricultural Experiment Station, July, 1950

(334) SHAFFER, P.; ANDERSON, D.; and WISCHKAEMPER, P.; "Packaging and Price-Marketing Produce in Retail Food Stores(A study of Improved Methods of Marketing Agricultural Products), USDA, MRR #278, Oct., 1958

(335) SHAW, B. T., "Losses in Agriculture", USDA, ARS-20-1, June, 1954

(336) SHEWAN, J. M., "The Present Status of Radiation Preservation of Food Products- Fish", Internation J. of Applied Radiation and Isotopes, 6, 1959

(337) SHEWAN, J. M.; and LISTON, J, "Experiments on the Irradiation of Fish with 4 Mev Cathode Rays and Cobalt-60 Gamma Rays", 2nd International Conference. Geneva, 1958

(338) SIMERL, L. E., "Testing Program for Irradiated Packaging Films", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, June, 1957

(339) SISMAN, O.; and WILSON, J. C., "Engineering Use of Damage Data", Nucleonics, 14, 9, Sept., 1956

(340) SKIBBE, A. G.; and PETERSON, G. T., "The Determination of the Suitability of Aluminum Containers for the Packaging of Irradiated Foods", U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Report #5, Feb., 1961

(341) SLAVIN, J. W., "Packaging of Refrigerated Fishery Products", The Refrigeration Research Foundation, Chicago, Illinois, Ms. G-66, May, 1960

(342) SMITH, E. H. G.,; and KAY, D. E., "The Utilization of Citrus Fruit", J. of Science Food and Agriculture, 11, April, 1960

(343) SMITH, J. E.; HAWKINS, C. W.; BERTILLION, A. W.; PIERCE, G. I., "The Effects of Radiation on the Functional and Physical Properties of Waxes, Wax Blends and Waxed Paper Products", U. S. Army, QuartermasterCorps, Proj. #7-84-01-002, Final Report, Oct., 1958

(344) SMITH, M. A.; and BERAHA, L., "Control of Post Harvest Diseases of Fruits and Vegetables by Radiation Treatments", U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Report #5, May, 1958

(345) SMITH, T. B., "Prepackaging Fresh Fruits and Vegetables", USDA, AMS, Nov., 1959

(346) SMITH, T. B.; and VALLDEJULI, J. J., "Fresh Product Prepackaging Practices in the United States", USDA, AMS, MRR #341, July, 1959

(347) SMITH, T. B; and BROWNING, J. W., "Fresh Fruit and Vegetable Prepackaging, Northeastern Region Operating Season- 1954-55", USDA, MRR#154, Feb., 1957

(348) SOBOLEV, I.; MEYER, J. A.; STANNETT, V.; and SZWARC, M., "Letters to the Editors-Permeability to Gases of Irradiated Polyethylene", J. of Polymer Science, 17, 85, (1955)

(349) SOMMER, N. F.; and LUVISI, D. A., "Choosing the Right Package for Fresh Fruit", Package Engineering, 5, 12, Dec., 1960

(350) SORENSEN, H. B., "Marketing Texas Green-Wrap Tomatoes", Texas Agricultural Experiment Station, Bulletin 861, May, 1957

(351) SPANGLER, R. L.; and IDE, L. E., "Preparation of Fresh Tomatoes for Market", USDA, Farmers' Bulletin #1291, 1955

(352) SPURLOCK, A. H., "Costs of Packing Tomatoes, F. O. B. Prices, and Returns to Growers, by Containers", Florida Agric. Experiment Sta., Agric. Economics Series No. 52-11, Oct., 1952

(353) SPURLOCK, A. H.; and HAMILTON, H. G., "Costs of Packing and Selling Florida Fresh Citrus Fruits, 1959-1960 Season", Florida Agric. Experiment Sta., Agric., Economics Mimeo Rpt. # 61-8, Feb., 1961

(354) Stanford Research Institute, "Insuring the Safety of Irradiated Foods", Research for Industry, 13,1, Jan.-Feb., 1961

(355) Stanford Research Institute, " Radiation Preservation of Selected Fruits and Vegetables", USAEC, SRIA-30, Contract No. AT(04-3)-115, Project Agreement No. 23, TID-4500 (16th Edition) Jan., 1961

(356) STEINBERG, M. A.; and CARVER, J. H., "Radiation Preservation of Fish", U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Report #8, April, 1959

(357) STEPHENSON, R., "Introduction to Nuclear Engineering", McGraw-Hill Book Company, Inc., 1954

(358) STEVENS, R. B., "The Fungi are Living Organisms", USDA, Yearbook of Agriculture-1953, Plant Diseases

(359) STOKES, D. R.; and HALE, P. W., "Consumer Packaging of California Grapes", Annual Convention of the California Grape & Tree Fruit League at Yosemite Park, California, April, 1958

(360) STOKES, D. R., "The Next Ten Years of Produce Packaging", USDA, Annual Convention of the Produce Packaging Association, Philadelphia, Pa., Sept., 1959

(361) STOKES, D. R., "Pear Packaging 1960-61", USDA, Oregon-Washington-California Pear Burea Conf., May, 1961

(362) STOKES, D. R., "Produce Packaging Potential", USDA, American Management Association Packaging Conf., April, 1955, Chicago, Ill.

(363) STOKES, D. R., "Produce Packaging Trends in the 60's", USDA, 12th Annual Merchandising & Management Conf., of the United Fresh Fruit & Vegetable Association, August, 1960

(364) STOKES, D. R., "Shipping Point Packaging Trends", USDA, New Jersey Marketing Inst., Nov., 1960

(365) STOKES, D. R., "The State of Produce Packaging Industry and a Look at Shipping Point Packaged Produce Offerings", USDA, Produce Packaging Assoc., Produce Seminar, Jan, 1961, New Orleans, La.

(366) STOKES, D. R., "Waste & Spoilage Losses in Merchandising Fresh Fruits & Vegetables in Bulk in Self-Service Food Stores and Statistical Supplement," USDA, Bureau of Agriculture Economics, Aug., 1947

(367) STOLLSTEIMER, J. F.; and SAMMET, L. L., "Packing Fresh Pears", California Agriculture, Oct., 1961

(368) SUN, K. H., "Effects of Atomic Radiation on High Polymers", Modern Plastics, 32, 1, 141 (1954)

(369) SWALLOW, A. J., "Radiation Chemistry of Organic Compounds", Pergamon Press, Inc., New York, N. Y., 1960

(370) TAIMUTY, S. I.; DELARUE, R. E.; OKADO, A.; and VELDEE, M. V., "A Comparative Study of the Effects of High and Low Intensity Radiations in Food Sterilization", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Report #9, August, 1957

(371) TAUSIG, F.; and DRAKE, M. P., "Activated Carbons as Odor Scavengers for Radiation-Sterilized Beef", Food Research, 24, 2, March-April, 1959

(372) THOMAS, W. H., "Tests Help You Compare Shipping Containers", Package Engineering, 5, 6, June, 1960

(373) THOMPSON, B., "Post-Harvest Treatments of Strawberries and Radishes with Cobalt-60 Irradiation", Proceedings of the Florida State Horticultural Society, 72, Oct., 1959

(374) THOMPSON, R. H.; BAUTISTA, F. R.; and CAIN, R. F., "Effect of Pre-Irradiation Heating Temperatures, Irradiation Level, and Storage Time at 34°F. on the Fresh Amino Acid Composition of Beef", J. of Food Sci., 26, 4, July-Aug., 1961

(375) THURSTON, C. E., "Proximate Composition of Nine-Species of Rockfish", J. of Food Science, 26, 1, Jan.-Feb., 1961

(376) TOENSMEIER, P. A., "New Market For Folding Cartons", Paperboard Packaging, Data Sheet, July, 1960

(377) TOLLE, W. E., "Protection of Paper-Packaged Fruits and Vegetables Displayed on Ice", USDA, MRR #293, Dec., 1958

(378) TOOTHMAN, J. S., "Survey of Distribution Practices for Prepackaged Frozen Meat, USDA, MRR#137, Sept., 1956

(379) TRAYLOR, H. D., "Some Effects of Use of Polyethylene Bags and Uniform Sizing on Retail Potato Sales," Cornell University, A. E. Res. 13, Feb., 1959

(380) TRELOGAN, H. C., "Packaging-- An Important Phase of Marketing Research (Talk)", Packaging Exposition, USDA, American Management Association, April, 1957, Chicago, Illinois

(381) TRESSLER, D. K.; and EVERS, C. F., " The Freezing Preservation of Foods-Volume I- Freezing of Fresh Foods", The AVI Publishing Co., Inc., 1957

(382) TRESSLER, D. K.; MCW. LEMON, J., et al, "Fish & Shellfish as Food, Characteristics of Fresh Fish: Appearance, Chemical Composition, & Nutritive Value", Marine Products of Commerce, Reinhold Publishing Corp., 1951

(383) TRESSLER, D. K.; and MCW. LEMON, J., et al, " Marine Products of Commerce", The Reinhold Publishing Corp., 1951

(384) TRESSLER, D. K., MCW. LEMON, J., et al, "Refrigeration and Freezing of Fish", Marine Products of Commerce, Reinhold Publishing Corp., 1951

(385) TRIPP, G., "Fresh Fruits & Vegetables", QMC, Inter. J. of Appl. Radiation & Isotopes, 6, Oct., 1959

(386) TRIPP, G. E., " Packaging for Irradiated Foods", Radiation Preservation of Food by the U. S. Army, Quartermaster Corps, No. 1, Aug., 1957

(387) TRIPP, G. E., "Packaging for Irradiated Foods", Presented before Packaging Institute, Hotel Statler, Cleveland, Ohio, Sept., 1956

(388) TRIPP, G. E., "Packaging for Irradiated Foods", International J. of Applied Radiation & Isotopes, 6, 1959

(389) TRIPP, G. E.; and CROWLEY, J. P., "Study and Development of Subsistence Containers", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Reports #1 thru #12, July, 1960

(390) TRUELSEN, T. A., "Irradiation of Fresh Fruits and Vegetables with Pasteurizing Doses", 1st Nordic Meeting on Food Preservation by Ionizing Radiations, Risö Report #16, July, 1960

(391) UHL, G. M., "Fish Sanitation", Los Angeles City Health Dept., Oct., 1957

(392) U. S. ARMY, QM CORPS, " Preservation of Food by Low-Dose Ionizing Energy", Quartermaster Res. & Engin., Command, Natick, Mass., Jan., 1961

(393) U. S. ARMY, QMF&CI, "Radiation Preservation of Foods Project", QMF&CI, Rpt. #4-59, March, 1959

(394) U. S. ARMY, QMF & CI, "Experimental Determination of Dose Distribution in a No. 10 Can", QMF&CI, Rpt. #32-57, Aug., 1957

(395) U. S. ARMY, QMF&CI, "Effect of Radiation Energy on Flexible Containers", QMF&CI, Activities Rpt. #9, (1957)

(396) U. S. ARMY, QMF&CI, "Food Preservation by Irradiation", QMF&CI, Activities Rpt. #9, Jan., 1957

(397) U. S. ARMY, QMF&CI, "Precooked Frozen Foods", QMF&CI, Symposium, Chicago, Illinois, Dec., 1955

(398) U.S. ARMY, OFFICE OF THE QM GENERAL, "Establishing Optimum Conditions for Storage and Handling of Semiperishable Subsistence Items", Conference, Research & Development Div., QM Corps, March, 1955

(399) U.S. ARMY, QMF&CI, "Low Temperature Test Methods and Standards for Containers", QMF&CI, Symposium, Chicago, Illinois, Sept., 1954

(400) U.S. ATOMIC ENERGY COMMISSION, "Food Irradiation and Associated Studies-Termination Report Part I ", NYO-3320, Sept., 1954

(401) U.S. DEPT. OF AGRICULTURE, AGRIC. MKTG. SERVICE, "Fresh Fruit and Vegetable Market News", AMS, Fruit & Vegetable Div., WS-40-61, Oct., 1961

(402) U.S. DEPT. OF AGRICULTURE, AGRIC. MKTG., SERVICE, "Fresh Fruit and Vegetable Market News", AMS, Fruit & Vegetable Div., WS-38-61, Sept., 1961

(403) U.S. DEPT. OF AGRICULTURE, ECONOMIC RES., SERVICE, "Supplement for 1960 to Consumption of Food in the U.S. 1909-52", Agriculture Handbook No. 62, Aug., 1961

(404) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG. SERVICE, "Food Costs-Retail Prices, Farm Prices, and Marketing Spreads", AMS, Rpt. #856, April, 1961

(405) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG. SERVICE, " The Vegetable Situation", AMS, TVS-139, Jan., 1961

(406) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG. SERVICE, "Supplement for 1956-60 to "Farm-Retail Spreads for Food Products", AMS, Marketing Economic Research Div., Rpt. #741, Jan., 1961

(407) U.S. DEPT. OF AGRICULTURE, " Agricultural Statistics-1960", U.S. Gov., Printing Office, Washington 25, D.C., -1961

(408) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, " Bibliography-Papers on Packaging Fresh Fruits and Vegetables", AMS, Transportation & Facilities Res., Div., 1961

(409) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, " The National Food Situation", AMS, NFS-94, Nov., 1960

(410) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG. SERVICE, "Supplement for 1959 to Measuring the Supply and Utilization of Farm Commodities", AMS, Agriculture Handbook #91, Sept., 1960

(411) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Fresh Fruit and Vegetable Shipments by Commodities, States and Months, Calendar Year 1959", AMS-36, (1959), April, 1960

(412) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Food Consumption and Dietary Levels of Households as Related to the Age of the Homemaker United States--by Region", AMS, Agric. Res., Service, Rpt. #14, Oct., 1959

(413) U.S. DEPT. OF AGRICULTURE, OFFICE OF ADMINISTRATOR, "Research on Packaging and Containers in the U.S. Dept. of Agriculture", Agric., Research Service, Nov., 1958

(414) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Farm-Retail Spreads for Food Products Cost, Prices...", AMS, Miscellaneous Publ. #741, Nov., 1957

(415) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, " Supplement for 1956 to Consumption of Food in the U.S. 1909-52", AMS, Agriculture Handbook #62, Sept., 1957

(416) U.S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, " Measuring the Supply and Utilization of Farm Commodities", AMS, Agriculture Handbook #91, Nov., 1955

(417) U.S. DEPT. OF AGRICULTURE, "The Commercial Storage of Fruits, Vegetables & Florist & Nursery Stocks", Agriculture Handbook #66, Sept., 1954

(418) U.S. DEPT. OF COMMERCE, " U.S. Army Panel Discussion on Radiation Preservation of Food", OTS-PB 121103, April, 1956

(419) U.S. DEPT. OF INTERIOR, " Commercial Fisheries Outlook October-December1959", U.S. Fish & Wildlife Service, Fishery Leaflet #336pp, Oct., 1959

(420) U.S. DEPT. OF INTERIOR, "Survey of the United States Shrimp Industry", U.S. Fish and Wildlife Service, 1, Fishery Rpt. #277, Nov. 1958

(421) U.S. DEPT. OF INTERIOR, "Production of Packaged Fish, by Sections, 1960 and 1959", U.S. Fish & Wildlife Service, CFS-#2542, 1961

(422) U.S. DEPT. OF INTERIOR, "Marketing Feasibility Study of Radiation Processed Fishery Products", U.S. Fish & Wildlife Service, WASH-1030, Isotopes-Industrial Technology, Dec., 1960

(423) U.S. DEPT. OF INTERIOR, "Handling Fresh Fish- Refrigeration of Fish Part II", U.S. Fish & Wildlife Service, Fishery Leaflet #428, Dec., 1956

(424) U.S. DEPT. OF INTERIOR, "Canned Fish & Byproducts", U.S. Fish & Wildlife Service, CFS-#2541, 1960

(425) U.S. DEPT. OF INTERIOR, " Fish & Shellfish Consumption in Public Eating and Drinking Places", U.S. Fish & Wildlife Service, Fisheries Rpt. #218, June, 1957

(426) U.S. DEPT. OF INTERIOR, "Factors to be Considered in the Freezing & Cold Storage of Fishery Products-Refrigeration of Fish Part 3", U.S. Fish & Wildlife Service, Fishery Leaflet #429, Jan., 1956

(427) U.S. DEPT. OF INTERIOR, "Distribution & Marketing of Frozen Fishery Products-Refrigeration of Fish Part 5", U.S. Fish & Wildlife Service, Fishery Leaflet #431, Oct., 1956

(428) U.S. DEPT. OF INTERIOR, "Imports & Exports of Fishery Products 1956-1960", U.S. Fish & Wildlife Service, CFS-#2578, 1961

(429) U.S. DEPT. OF INTERIOR, "Frozen Fish Report", U.S. Fish & Wildlife Service, CFS-#2584, April, 1961

(430) U.S. DEPT. OF INTERIOR, "1960 Annual Report of the Secretary of the Interior", 1960

(431) U.S. DEPT. OF INTERIOR, "Canned Fish Consumer Purchases by Family Characteristics (Oct. 1958-March 1959)", U.S. Fish & Wildlife Service, Fishery Leaflet #478h, Aug., 1959

(432) U.S. DEPT. OF INTERIOR, "A Market Development Plan for the New England Groundfish Industry", U.S. Fish & Wildlife Service, Circular 53, July, 1958

(433) UOTA, M., "Evaluation of Polyethylene Film Liners for Packaging Emperor Grapes for Storage", Proceedings of the American Society for Horticultural Science, 70, 1957

(434) URBAIN, W.M., "Progress and Problems in Radiation Processing of Food", J. of Agricultural and Food Chemistry, 8, 5, Sept.-Oct., 1960

(435) URBAIN, W.M., "Progress and Problems in Radiation Processing of Food", Preprint Paper #52, Nuclear Engin. & Sci., Conf., April, 1960

(436) VAS, K.; KUTZ, N.; LANG, A.; ORBANI, T., "Factors Involved in the Interpretation of Mold Counts of Tomato Products", Food Tech. 13, 6, June, 1959

(437) VERSEPUT, H.V.; and AID, J.J., "Effect of Radiation on Papermaking Materials", Continental Can Company, Inc., Folding Carton & Drum Div., Final Report, Project No. R-3-57-10, June, 1959

(438) VILLARREAL, F.; LUH, B.S.; and ROMANI, R.J., "High-Velocity Electron Irradiation of Tomato Paste", Food Tech. 15, 4, 1961

(439) VOYVODIC, L., "Design Studies on Cesium-137 as a Source for High Level Gamma Irradiators", Armour Research Foundation, ARF-1150-12, Ec., 1960

(440) WAGENAAR, R. O.; DACK, G. M.; and MURRELL, C. B., "Studies on Purified Type a Clostridium Botulinum Toxin Subject to Ultracentrifugation and Irradiation", Food Research, 24, 1, Jan.-Feb., 1959

(441) WATT, B. K.; MERRILL, A. L.; ORR, M. L.; and WU, W. T., "Composition of Foods -- Raw, Processed, Prepared", U. S. Dept. of Agric., Agriculture Handbook #8, June, 1950

(442) WHEATON, E.; PRATT, G. B.; and JACKSON, J. M., "Radioresistance of Five Strains of Clostridium Botulinum in Selected Food Products", Jl. of Food Science, 26, 4, July-Aug., 1961

(443) WHITE, D., Inc., "Survey of Packaging Practices in the Food and Grocery Industry", Folding Paper Box Assoc., of America, Chicago, Illinois

(444) WHITNEY, W. K.; NELSON, S. O.; and WALKDEN, H. H., "Effects of High-Frequency Electric Fields on Certain Species of Stored-Grain Insects", U. S. Dept. Agriculture, Agric. Mktg. Service, Marketing Research Rpt. #455, March, 1961

(445) WILSON, G. M., "The Treatment of Meats with Ionizing Radiations. II. Observations on the Destruction of Thiamine", Jl. of Sci. of Food & Agric. 10, May, 1959

(446) WINSTON, J. R.; HRUSCHKA, H.; CUBBEDGE, R., "Effect of Packinghouse Treatments, Temperatures in Transit & Containers on Decay in Tangerines", U. S. Dept. Agriculture, Agric. Mktg. Service, #125, March, 1958

(447) WOODMANSEE, C. W.; MCCLENDON, J. H.; and SOMERS, G. F., "Chemical Changes Associated with the Ripening of Apples and Tomatoes", Chemistry and Biochemistry of Foods, 24, 5, Sept.-Oct., 1959

(448) WRIGHT, T. R., "Physiological Disorders", Plant Diseases- Yearbook of Agriculture, U. S. Dept. of Agriculture, 1953

(449) WRIGHT, T. R.; and SMITH, E., "Cuts, Bruises, and Spoilage", Plant Diseases- Yearbook of Agriculture, U. S. Dept. of Agriculture, 1953

(450) BROOKE, R. O., "Radiation-Preservation of Fishery Products," Progress Report, Jan. 1 to March 31, 1962, USDI, Tech. Lab., Gloucester, Mass.

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ASTM, "Exposure of Polymer Materials to High Energy Radiation", ASTM D 1672-59 T, Revised, Sept. 10, 1959

BOVEY, F. A., "Effects of Ionizing Radiation on Natural and Synthetic High Polymers", Interscience Publishers, Inc., N. Y., 1958

BROOKS, H., "Nuclear Radiation Effects in Solids", Annual Review of Nuclear Sc., 6, 1956

CARROLL, J. G.; and BOLT, R. O., "Radiation Effects on Organic Materials", Nucleonics, 18, 9, Sept. 1960

CHARLESBY, A., "Atomic Radiation and Polymers", Pergamon Press, New York, N. Y., 1960

COLLINS, C. G.; and CALKINS, V. P., "Radiation Damage to Elastomers, Plastics, and Organic Liquids," APEX-261, TID-4500 (11th Edition), Sept., 1956

CROPPER, W. H., "Radiation-Induced Coloration in Glass", SCR-79 (Reprint) Aug., 1959

DIENES, G. J., "Radiation Effects in Solids", Annual Review of Nuclear Sc., 11, 1953

FUKADA, E.; STEPHENS, R. W. B.; CHARLESBY, A., "Dynamic Mechanical Properties of Irradiation High Density Polyethylene", Physics and Chemistry of Solids, 16, 1/2, Pergamon Press, Nov., 1960

HARRINGTON, R.; and GIBERSON, R., "Chemical and Physical Changes in Gamma-Irradiated Plastics", Modern Plastics, Nov., 1958

PECKNER, D., "Radiation Damage in Metals", Engineering and Design, Jan., 1960

REINSMITH, G., "Nuclear Radiation Effects on Materials", ASTM Bulletin, (TP-185) Sept., 1958

SEITZ, F.; and KOEHLER, J. S., "Radiation Disarrangement of Crystals", Impurities and Imperfections, Amer. Society for Metals, 1955

SISMAN, O.; and WILSON, J. C., "Engineering use of Damage Data", Nucleonics, 14, 9, Sept. 1956

SUN, K. H., "Effects of Atomic Radiation on High Polymers", Modern Plastics, 32, 1, 141 (1954)

SWALLOW, A. J., "Radiation Chemistry of Organic Compounds", Pergamon Press, Inc., New York, N. Y., 1960

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - GENERAL

DESROSIER, N. W.; and ROSENSTOCK, H. M., "Radiation Effects on Packaging Materials", Radiation Tech., in Food, Agric. and Biology, AVI Publ. Co., Inc., 1960

TRIPP, G. E., "Packaging for Irradiated Foods", Radiation Preservation of Food by the U. S. Army, Quartermaster Corps, No. 1, Aug., 1957

TRIPP, G. E., "Packaging for Irradiated Foods", Presented before Packaging Institute, Hotel Statler, Cleveland, Ohio, Sept., 1956

TRIPP, G. E., "Packaging for Irradiated Foods", International J. of Applied Radiation & Isotopes, 6, 1959

U. S. ARMY, QM CORPS, "Preservation of Food by Low-Dose Ionizing Energy", Quartermaster Res. & Engin., Command, Natick, Mass., Jan., 1961

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - PAPER

CRAIN, R. C., "Testing Irradiated Food Packaging Papers", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Prt., June, 1958

FEAZEL, C. E., "Determination of Effect of Packaging Materials on the Properties of Irradiated Foods", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Final Rpt., March, 1958

FEAZEL, C. E.; MOSES, B. C.; BURKS, R. E., et al, "A Study of Irradiation in Combination with Model Food Systems on the Functional Properties of Food Containers", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #10, March, 1958

LARSON, W. S., "Investigation of Containers for Radiation Preservation of Food", U. S. Army Quartermaster Corps., Project #7-84-01-002, Final Report, Dec., 1959

RUMBERGER, G. G., "Effect of Ionizing Radiation on Materials for Carton Construction", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Final Report, Sept., 1960

SALUNKHE, D. K.; POLLARD, L. H.; GERBER, R. K.; WILCOX, E. B.; and SIMON, M., "Packaging Effects on the Flavor and Shelf Life of Gamma-Irradiated Fresh Fruits and Vegetables," Package Engineering 4:2 (1959)

SMITH, J. E.; HAWKINS, C. W.; BERTILLION, A. W.; PIERCE, G. I., "The Effects of Radiation on the Functional and Physical Properties of Waxes, Wax Blends and Waxed Paper Products", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, Oct., 1958

VERSEPUT, H. V.; and AID, J. J., "Effect of Radiation on Papermaking Materials", Continental Can Company, Inc., Folding Carton & Drum Div., Final Report, Project No. R-3-57-10, June, 1959

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT- PLASTIC

BERSCH, C. F.; STROMBERG, R. R.; and ACHHAMMER, B. G., "Effect of Radiation on Plastic Films", Modern Packaging, Aug., 1959

BESSE, A. L.; and THOMPSON, D. F., "Packaging for Irradiated Subsistence Items", U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Rpt. #5, March, 1958

BOVEY, F. A., "Effects of Ionizing Radiation on Natural and Synthetic High Polymers", Interscience Publishers, Inc., N. Y., 1958

FEAZEL, C. E.; BURKS, R. E.; MOSES, B.; and TRIPP, G. E., "Testing Packages for Irradiated Foods", Packaging Engin., 5, 4, April, 1960

FEAZEL, C. E.; BURKS, R. E.; MOSES, B. C.; and TRIPP, G. E., "Shed New Light on Stress Cracking", Package Engineering, 7, 2, Feb. 1962

FEAZEL, C. E., "Determination of Effect of Packaging Materials on the Properties of Irradiated Foods", U. S. Army, Quartermaster, Corps, Project #7-84-01-002, Final Rpt., March, 1958

FEAZEL, C. E.; MOSES, B. C.; BURKS, R. E., et al, "A Study of Irradiation in Combination with Model Food Systems on the Functional Properties of Food Containers," U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #10, March, 1958

HATHAWAY, C. T., "Evaluation of Films for Irradiation Packaging of Foods", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #5, Jan., 1959

KRASNANSKY, V. J., "Properties of Irradiated Non-Metallic Packaging Materials", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt., #6358, April, 1959

LARSON, W. S., "Investigation of Containers for Radiation Preservation of Food", U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Final Report, Dec., 1959

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - PLASTIC (con't)

LECLAIR, H. C.; and COBBS, W. H., JR., "Effects of Radiation on Plastic Packaging Films", Industrial & Engineering Chemistry 50, March, 1958

PROCTOR, B. E., "Cathode-ray Irradiation of Cellophanes", Modern Packaging, Jan., 1957

PROCTOR, B. E., "Procurement of Services Pertinent to the Determination of Bacterial Resistance of Packages", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, March, 1958

SALUNKHE, D. K.; POLLARD, L. H.; GERBER, R. K.; WILCOX, E. B.; and SIMON, M., "Packaging Effects on the Flavor and Shelf Life of Gamma-Irradiated Fresh Fruits and Vegetables", Package Engineering 4:2 (1959)

SIMERL, L. E., "Testing Program for Irradiated Packaging Films", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, June, 1957

TRIPP, G. E.; and CROWLEY, J. P., "Study and Development of Subsistence Containers", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Reports #1 thru #12, July, 1960

U. S. ARMY, QMF&CI, "Effect of Radiation Energy on Flexible Containers", QMF&CI, Activities Rpt. #9, (1957)

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - METAL

BESSE, A. L.; and THOMPSON, D. F., "Packaging for Irradiated Subsistence Items", U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Rpt. #5, March, 1958

HEINEN, J. M.; DAVIS, R. B.; and DOWLING, J. E., "Radiation Sterilization of Canned Foods", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Final Rpt., Oct., 1956

O'BRIEN, R., "Investigation of the Effects of Irradiation on Foods Packaged in Hermetically Sealed Aluminum Foil Containers", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Report #1, Aug., 1958

PRATT, G. B.; and WILBUR, A. C., "Corrosion Studies of Irradiated Canned Food", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Annual Report #5, Sept., 1960

PRATT, G. B., "Research Study on Can Enamels as Part of the Radiation Preservation of Foods Program", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, May, 1960

SALUNKHE, D. K.; POLLARD, L. H.; GERBER, R. K.; WILCOX, E. B.; and SIMON, M., "Packaging Effects on the Flavor and Shelf Life of Gamma-Irradiated Fresh Fruits and Vegetables", Package Engineering 4:2 (1959)

SKIBBE, A. G.; and PETERSON, G. T., "The Determination of the Suitability of Aluminum Containers for the Packaging of Irradiated Foods", U. S. Army, Quartermaster Corps, Project No. 7-84-01-002, Report #5, Feb., 1961

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - LAMINATES

COLLINS, H. E., "Design of Containers for Irradiated Foods", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, July, 1959

FEAZEL, C. E., "Determination of Effect of Packaging Materials on the Properties of Irradiated Foods", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Final Rpt., March, 1958

FEAZEL, C. E.; MOSES, B. C.; BURKS, R. E., et al, "A Study of Irradiation in Combination with Model Food Systems on the Functional Properties of Food Containers", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt., #10, March, 1958

LARSON, W. S., "Investigation of Containers for Radiation Preservation of Food", U. S. Army Quartermaster Corps, Project No. 7-84-01-002, Final Report, Dec., 1959

TRIPP, G. E.; and CROWLEY, J. P., "Study and Development of Subsistence Containers", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Reports #1 thru #12, July, 1960

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - GLASS

BARBER, S. W.; FORRY, K. E.; and DEGERING, E. F., "Effects of Electron Bombardment on Elasticity and Mechanical Damping of Certain Glasses", Amer. Ceramic Soc. Symposium on Radiation Effects, Oct., 1959

BARKER, R. S.; and RICHARDSON, D. A., "Effect of Gamma Radiation on Spectral Transmission of Some Commercial Glasses", Jl. of the Amer. Ceramic Soc., 44, 11, Nov., 1961

CROPPER, W. H., "Radiation-Induced Coloration in Glass", SCR-79 (Reprint) Aug., 1959

MIKE, T. M.; STEIERMAN, B. L.; and DEGERING, E. F., "Effects of Electron Bombardment on Properties of Various Glasses", Amer. Ceramic Soc. Symposium on Radiation Effects, Oct., 1959

TRIPP, G. E., "Packaging for Irradiated Foods", Radiation Preservation of Food by the U. S. Army, Quartermaster Corps, No. 1, Aug., 1957

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - WOOD

KARPOV, V. L.; MALINSKY, Y. M.; and SERENKOV, V. I., "Radiation Makes Better Woods and Copolymers", Nucleonics, 18, 3, March, 1960

LAWTON, E. J.; BELLAMY, W. D.; HUNGATE, R. E.; BRYANT, M. P.; and HALE, E., "Some Effects of High Velocity Electrons on Wood", Science, 113, #2936, April, 1951

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - ADHESIVES AND WAXES

SMITH, J. E.; HAWKINS, C. W.; BERTILLION, A. W.; PIERCE, G. I., "The Effects of Radiation on the Functional and Physical Properties of Waxes, Wax Blends and Waxed Paper Products," U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, Oct., 1958

BEHAVIOR OF PACKAGING MATERIALS IN FOOD IRRADIATION ENVIRONMENT - COLORANTS

CHARLESBY, A., "Atomic Radiation and Polymers", Pergamon Press, New York, N. Y., 1960

CORNISH, E. H.; and SCI,, M., "The Resistance of Coloured Polyethylene to Irradiation", Plastics, 25, 278, Dec., 1960

CRAIN, R. C., "Testing Irradiated Food Packaging Papers", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., June, 1958

KECK, F. L., "Effects of Beta Irradiation on a Typical Metal Finish", Official Digest, Sept., 1958

RUMBERGER, G. G., "Effect of Ionizing Radiation on Materials for Carton Construction", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, Sept., 1960

ASPECTS OF RADIATION SOURCE DESIGN AND FOOD CONTAINER DESIGN

AEBERSOLD, P. C., "The USA Research Program on Low Dose Radiation Processing of Foods", Symposium on Isotopes Applications Tenth Pacific Sc. Cong., Honolulu, Aug., 1961

CHARM, S. E.; GOLDBLITH, S. A.; and PROCTOR, B. E., "Theoretical Considerations in Food Processing by Gamma Radiations - II A Simplified Mathematical Procedure for Evaluating Gamma Radiation Processes Inside Hallow Cylinder Sources," Food Tech., 12, 5, May, 1958

CHRISTENSEN, C. J.; JACOBSEN, A. T.; KLINGER, Q.; and EVANS, M. D., "Dugway Cobalt-6- Irradiation Facility", Tech., Rpt., Da-18-108-CML-5347, Jan., 1959

EUKEL, W. W.; and HUBER, W., "Tooling Up for Low Dose Irradiation Processing of Fresh Foods", Food Tech., 14, 4, April, 1960

GOLDBLITH, S. A.; and PROCTOR, B. E., "Evaluation of Food Sterilization Efficiency", Nucleonics, 10, 9, Sept., 1952

KRAYBILL, H. F.; and BRUNTON, D. C., "Commercialization Technology and Economics in Radiation Processing", Agric. and Food Chemistry, 8, 5, Sept.-Oct., 1960

MANOWITZ, B.; KUHL, O. A.; GALANTE, L.; BRETTON, R.H.; and ZWICKLER, S., "Experimental Parametric Study of Large-Scale Co^{60}, NA^{24}, and CS^{137} Slab Irradiators", Large Radiation Sources in Industry, International Atomic Energy Agency, 1, 1960

U. S. ARMY, QMF&CI, "Experimental Determination of Dose Distribution in a No. 10 Can", QMF&CI, Rpt. #32-57, Aug., 1957

VOYVODIC, L., "Design Studies on Cesium-137 as a Source for High Level Gamma Irradiators", Armour Research Foundation, ARF-1150-12, Ec., 1960

PRODUCTION AND PROCESSING OF FISHERY PRODUCTS

ALBANO, G. A., "Monthly Summary of Chicago's Wholesale Market Fresh and Frozen Fishery Products Receipts, Prices, and Trends," USDI Bureau of Commercial Fisheries, March, 1961

ANDERSON, A. W., "Fresh and Frozen Fish Buying Manual," USDI Fish and Wildlife Service, Circular #20

Biostatistical Section, "Statistical Report of Fresh, Canned, Cured and Manufactured Fishery Products Year 1960," State of Calif., Dept., of Fish & Game, Circular #35, 1961

DASSOW, J. A.; POTTINGER, S. R.; and HOLSTON, J., "Preparation, Freezing, and Cold Storage of Fish, Shellfish, and Precooked Fishery Products", U. S. Dept. of Interior, Fishery Leaflet 430, Part 4, 1956

FINN, D. B., "Fish and Great Potential Food Supply", Food & Agric. Organization of the UN, World Food Problems, #3, Rome, 1960

JOHNSON, H.; and BREAKIRON, P. L., "Protecting Perishable Foods During Transportation by Truck", USDA, Handbook #105, Dec., 1956

MCKERNAN, D. L., Bureau of Commercial Fisheries "Operations of the Bureau of Commercial Fisheries Under the Saltonstall-Kennedy Act, Fiscal Year 1959," USDI, C.F.S., No. 2578, 1959

O'BRIEN, J. J., "New England Fisheries--Annual Summary, 1960", USDI, A48: 923, 1960

POWER, E. A., "Fisheries of the United States and Alaska, 1958", USDI, Fishery Leaflet 393, Rev., March, 1959

POWER, E. A., "Fisheries of the United States 1960 - A Preliminary Review", USDI, Fishery Leaflet 393, April 1961

POWER, E. A., "Fishery Statistics of the United States", USDI, Statistical Digest #44, 1957

REARDON, C. M., "Seattle and Astoria Landings, Receipts, and Value of Fishery Products", USDI, Bureau of Commercial Fisheries, 1960

RISOLI, T. J., "New York City's Wholesale Fishery Trade", USDI, A56: 875, 1960

ROYCE, W. F.; BULLER, R. J.; and PREMETZ, E. D., "Decline of the Yellowtail Flounder (Limanda Ferruginea) Off New England", USDI, Fish & Wildlife Service, 59, Fishery Bulletin 146, 1959

SAMSON, V. J., "California Fishery Market News Monthly Summary", USDI, M13,923, Feb., 1961

TRESSLER, D. K.; and MCW. LEMON, J., et al, "Marine Products of Commerce", The Reinhold Publishing Corp., 1951

TRESSLER, D. K., MCW. LEMON, J., etal, "Refrigeration and Freezing of Fish", Marine Products of Commerce, Reinhold Publishing Corp., 1951

U.S. DEPT. OF AGRICULTURE, "Agricultural Statistics-1960", U. S. Gov., Printing Office, Washington 25, D. C., -1961

U.S. DEPT. OF INTERIOR, "Commercial Fisheries Outlook October-December 1959", U. S. Fish & Wildlife Service, Fishery Leaflet #336pp, Oct., 1959

U.S. DEPT. OF INTERIOR, "Survey of the United States Shrimp Industry", U.S. Fish and Wildlife Service, 1, Fishery Rpt. #277, Nov. 1958

U.S. DEPT. OF INTERIOR, "Handling Fresh Fish - Refrigeration of Fish Part II", U. S. Fish & Wildlife Service, Fishery Leaflet #428, Dec., 1956

U.S. DEPT. OF INTERIOR, "Fish & Shellfish Consumption in Public Eating and Drinking Places", U. S. Fish & Wildlife Service, Fisheries Rpt. #218, June, 1957

U.S. DEPT. OF INTERIOR, "Factors to be Considered in the Freezing & Cold Storage of Fishery Products - Refrigeration of Fish Part 3", U. S. Fish & Wildlife Service, Fishery Leaflet #429, Jan., 1956

U.S. DEPT. OF INTERIOR, "A Market Development Plan for the New England Groundfish Industry", U.S. Fish&Wildlife Service, Circular 53, July, 1958

FOOD TECHNOLOGY OF NON-IRRADIATED FISHERY PRODUCTS

ANDERSSON, K.; and DANIELSON, C. E., "Storage Changes in Frozen Fish: A Comparison of Objective and Subjective Tests", Food Tech., 15, 2, Feb., 1961

BYSTEDT, J.; SWENNE, L.; and AAS, H. W., "Determination of Trimethylamine Oxide in Fish Muscle", Jl. Sc. Food Agric., 10, June, 1959

DEES, L. T., "A List of the Fishery Bulletins of the United States Fish and Wildlife Service", U.S. Dept. of Interior, Fishery Leaflet 509, March, 1961

FARBER, L.; and LERKE, P. A., " A Review of the Value of Volatile Reducing Substances for the Chemical Assessment of the Freshness of Fish and Fish Products", Food Tech., Dec., 1958

FARBER, L.; and LERKE, P., "Studies on the Evaluation of Freshness and on the Estimation of the Storage Life of Raw Fishery Products", Food Tech., 15, 4, April, 1961

JONES, N. R., "Browning Reactions & The Loss of Free Amino Acid and Sugar From Lyophilized Muscle Extractives of Fresh & Chill-Stored Codling (Gadus Callarias)," Biochemical & Chemical Res. on Food, 24, 6, Nov.-Dec., 1959

JONES, N. R., "The Free Amino-Acids of Fish. II-Fresh Skeletal Muscle from Lemon Sold (Pleuronectes Microcephalus), Jl. Sc. of Food Agric., May, 1959

KLINE, E. F.; ABBEY, A.; FIRMAN, M.C.; and HOPPER, P. F., "Thermal and Nonthermal Degradation of Acronize Chlortetracycline in Fish and Some Shellfish, Food Tech., June, 1960

LISTON, J.; CHAPE, J.G.; and STERN, J.A., "The Spoilage of Pacific Coast Rockfish I. Spoilage in Ice Storage", Food Technology, Jan., 1961

LOVERN, J. A.; OLLEY, J.; and WATSON, H.A., "Changes in the Lipids of Cod During Storage in Ice", J. of Science Food Agric. 10, June, 1959

MACLEOD, R. A.; JONAS, E. E.; and MCBRIDE, J. R., "Sodium Ion, Potassium Ion, and Weight Changes in Fish Held in Refrigerated Sea Water and Other Solutions", Agricultural and Food Chemistry, 8, 2, March-April, 1960

MOORJANI, M. N.; IYENGAR, J. R.; VISWESWARIAH, K. et al, "Changes in the Total Volatile Base, Volatile Reducing Substances and Bacterial Count as Indices of Fresh Water Fish Spoilage", Food Tech., Aug., 1958

SCATTERGOOD, L. W., "English Translations of Fishery Literature Additional Listings, 1957", USDA, Rpt. #227, Aug., 1957

THURSTON, C. E., "Proximate Composition of Nine-Species of Rockfish", J. of Food Science, 26, 1, Jan.-Feb., 1961

TRESSLER, D. K.; MCW. LEMON, J., et al, "Fish & Shellfish as Food, Characteristics of Fresh Fish: Appearance, Chemical Composition, & Nutritive Value", Marine Products of Commerce, Reinhold Publishing Corp., 1951

UHL, G. M., "Fish Sanitation", Los Angeles City Health Dept., Oct., 1957

PACKAGING NON-IRRADIATED FISHERY PRODUCTS

Anon., "Fish in Film", Modern Packaging, Jan., 1959

CARLE, L. A., "Keeping Quality of Chilled Dungeness Crab Meat Packed in Hermetically-Sealed Containers", Commercial Fisheries Review, 16, 11, Part I, and 17, 2, Part II

GUILFOY, R. F.; and JOHNSON, H. D., "Suggested Methods for Checking Temperatures of Fresh and Frozen Food Shipments", USDA, Marketing Research Rpt., #150, Dec., 1956

HEERDT, M., "Wrapping Materials for Frozen Fish", USDI, Fishery Leaflet 213, Jan., 1947

HORTON, R. E., "Endless Conveyor Table Imrpves Fish Fillet Packaging", Package Engin., Dec., 1959

PETERS, J. A., "Review of Problems in Handling and Packaging Chilled Fishery Products", Fishing Gazette, MS. G-71, Annual Review Number, 1961

SLAVIN, J. W., "Packaging of Refrigerated Fishery Products", The Refrigeration Research Foundation, Chicago, Illinois, Ms. G-66, May, 1960

TOENSMEIER, P. A., "New Market for Folding Cartons", Paperboard Packaging, Data Sheet, July, 1960

U.S. DEPT. OF INTERIOR, "Production of Packaged Fish, by Sections, 1960 and 1959", U.S. Fish & Wildlife Service, CFS-#2542, 1961

U.S. DEPT. OF INTERIOR, "Canned Fish - Byproducts", U. S. Fish & Wildlife Service, CFS-#2541, 1960

RADIATION PASTEURIZATION OF FISHERY PRODUCTS

BENDER, M.; MIYAUCHI, D. T.; and CARVER, J. H., "Progress Report on Radiation Pasteurization & Sterilization of Seafood", Quick Frozen Foods, 20, 11, June, 1958

BROWNELL, L. E.; and PUROHIT, S. N., "Combining Gamma Radiation, Refrigeration", Refrigerating Engin., June, 1956

BROWNELL, L. E.; KUIPERS, K.; and EZMAN, L., "Radiopasteurization of Food", U. S. Army, Quartermaster Corps., Project 7-84-01-002, Rpt. #5, July, 1958

CHARM, S. E.; GOLDBLITH, S.A.; and PROCTOR, B. E., "Theoretical Considerations in Food Processing by Gamma Radiations - II A Simplified Mathematical Procedure for Evaluating Gamma Radiation Processes Inside Hallow Cylinder Sources", Food Tech., 12, 5, May, 1958

DENNY, C. F.; BOHRER, C. W.; PERKINS, W. E.; and TOWNSEND, C. T., "Destruction of Clostridium Botulinum by Ionizing Radiation", Food Radiation, 24, 1, Jan.-Feb., 1959

FEAZEL, C. E.; BURKS, R. E.; MOSES, B.; and TRIPP, G. E., "Testing Packages for Irradiated Foods", Packaging Engin., 5, 4, April, 1960

LERKE, P. A.; FARBER, L.; and HUBER, W., "Preservation of Fish and Shellfish by Relatively Low Doses of Beta Radiation and Antibiotics", Food Technology, 15, 3, March, 1961

MACLEAN, D. P.; and WELANDER, C., "The Preservation of Fish with Ionizing Radiation: Bacterial Studies", Food Tech., May, 1960

MILLER, S. A.; LICCIARDELLO, J. J.; NICKERSON, J.T. R.; and GOLDBLITH, S. A., "A Literature Survey on the Effects of Ionizing Radiations on Sea Foods with Respect to Wholesomeness Aspects", US, AEC, Rpt., #9656, TID-11610-1959

MIYAUCHI, D. T., "Irradiation Preservation of Pacific Northwest Fish. I. Cod Fillets", Food Tech., Aug., 1960

NICKERSON, J.T.R.; LOCKHART, E. E.; and PROCTOR, B. E., "Ionizing Radiations for the Control of Fish Spoilage", Food Tech., 8, 1, Jan., 1954

NICKERSON, J.T.R.; GOLDBLITH, S. A.; MILLER, S. A., et al, "Outline of Projects to Determine the Feasibility of Radiation Preservation of Marine Products", USAEC, TID-6700, April, 1961

PROCTOR, B. E.; GOLDBLITH, S.; NICKERSON, J.T.R.; and FARKAS, D. F., "Evaluation of the Technical, Economic and Practical Feasibility of Radiation Preservation of Fish", USAEC, NYO-9182, Task VI, Contract #AT(30-1)2329, 1959

PROCTOR, B. E.; NICKERSON, J.T.R.; and GOLDBLITH, S. A., "Storage of Haddock", Refrigerating Engineering, April, 1950

SCHMIDT, D. F.; and NANK, W. K., "Radiation Sterilization of Food. I. Procedures for the Evaluation of the Rad. Resistance of Spores of Clostridium Botulinum in Food Products", Food Research, 25, 3, May-June, 1960

SHEWAN, J.M., "The Present Status of Radiation Preservation of Food Products-Fish", International J. of Applied Radiation and Isotopes, 6, 1959

STEINBERG, M. A.; and CARVER, J. H., "Radiation Preservation of Fish", U.S. Army, Quartermaster Corps, Project No. 7-84-01-002, Report #8, April, 1959

TRIPP, G. E., "Packaging for Irradiated Foods", Radiation Preservation of Food by the U. S. Army, Quartermaster Corps, No. 1, Aug., 1957

TRIPP, G. E., "Packaging for Irradiated Foods", Presented before Packaging Institute, Hotel Statler, Cleveland, Ohio, Sept., 1956

U.S. DEPT. OF INTERIOR, "Marketing Feasibility Study of Radiation Processed Fishery Products", U. S. Fish & Wildlife Service, WASH-1030, Isotopes-Industrial Technology, Dec., 1960

WAGENAAR, R. O.; DACK, G.M.; and MURRELL, C. B., "Studies on Purified Type a Clostridium Botulinum Toxin Subject to Ultracentrifugation and Irradiatio", Food Research, 24, 1, Jan.-Feb. 1959

RELATED INFORMATION ON FISHERY PRODUCTS

ANDERSON, D. L; SHAFFER, P. F., "Improved Handling of Frozen Foods in Retail Stores", USDA, Marketing Research Report #104, Sept., 1955

BITTING, H. W., "New Developments in the Frozen Food Industry...", USDA, Marketing Research Rpt., #236, May, 1958

BROWNELL, L. E.; NEHEMIAS, J. V.; and BULMER, J. J., "Proposed New Methods of Wholesaling Fresh Meat Based on Pasteurization by Gamma Irradiation", USAEC, AECU-3043, Project 1943-7, Contract #AT(11-1)-162, Dec., 1954

Consumer Union, "Frozen Fried Fish Sticks", Consumer Rpts., Feb., 1961

HEERDT, M. B.; BUCHER, D. L.; and STANSBY, M. E., "Refrigerated Locker Storage of Fish and Shellfish", USDI, Fishery Leaflet 128, June, 1949

JOHNSON, H. D.; GERRITY, M. V.; and GARVER, C. E., "Transportation Tests of Fresh Meat and Packinghouse Products in Refrigerator Cars", USDA AMS-17, March, 1955

U.S. DEPT. OF INTERIOR, "Distribution & Marketing of Frozen Fishery Products-Refrigeration of Fish Part 5", U.S. Fish & Wildlife Service, Fishery Leaflet #431, Oct., 1956

U.S. DEPT. OF INTERIOR, "Imports & Exports of Fishery Products 1956-1960", U.S. Fish & Wildlife Service, CFS-#2578, 1961

U.S. DEPT. OF INTERIOR, "Frozen Fish Report", U.S. Fish & Wildlife Service, CFS-#2584, April, 1961

U.S. DEPT. OF INTERIOR, "Canned Fish Consumer Purchases by Family Characteristics (Oct. 1958-March 1959)", U.S. Fish & Wildlife Service, Fishery Leaflet #478h, Aug., 1959

PRODUCTION AND PROCESSING OF FRESH FRUITS AND VEGETABLES

Anon., "U. S. Fruit Acreage - Crops - Crop Utilization - Grower Prices", Yearbook Number, Canner Packer, Sept., 1960

Anon., "Industry Reference Data", Yearbook Number, Canner Packer, Sept., 1960

BROMELL, J. R., "Survey of Wholesale Grocers' Profit and Loss Figures", Compilation and Analysis of 1955 & 57 Operating Results, U. S. Wholesale Grocers' Assoc., Inc., Washington, D. C.

BURK, M. C., "Consumption of Processed Farm Foods in the United States", USDA, Marketing Research Rpt. #409, June, 1960

BURK, M. C., "Trends and Patterns in U. S. Food Comsumption", USDA, Agric. Handbook #214, June, 1961

COLLIER, J. E., "Citrus Fruits, Grapes, Berries, and Nuts: 1954", U. S. Dept. of Commerce, Bureau of Census, 1954

COMIN, D., "Successful Storage of Peaches Depends on Maturity and Post-Ripening", Ohio Farm and Home Research, July-Aug., 1955

ENGER, M. R.; and BREAKIRON, P. L., "Efficiency and Potential Economies of Dual-Purpose Shipping Containers for Mature-Green Tomatoes", USDA, Marketing Research Rpt. #257, July, 1958

FUTRELL, G.; and KOLMER, L., "Consumer Marketing Handbook, III Fruits and Vegetables", Iowa State University of Sc. and Tech., May, 1961

GARTNER, J.; and KOLMER, L., "Consumer Marketing Bulletin", II. Economic Information for Consumer Marketing Programs, Iowa State Univ. of Sc. & Tech., May, 1961

HARDING, P. L.; WIANT, J. S.; and HRUSCHKA, H. W., "The Effect of Pre-Storage Packinghouse Treatments on the Control of Decay of Florida Oranges During Storage At Orlando, Florida & New York City, 1951", USDA, AMS-233, April, 1958

HEFLIN, L., "Fresh Fruit and Vegetable Prices 1960", USDA, Statistical Bulletin #285, May, 1961

MACLINN, W. A., "Commodity Storage Manual", Refrigeration Research Foundation, Copyright, 1957

MORRISON, W. W., "Preparing Peaches for Market", USDA, Marketing Bulletin #9, Aug., 1960

MORRISON, W. W., "Preparing Strawberries for Market", USDA, Framers' Bulletin #1560, Nov., 1959

MOTTS, G. N., "Marketing Handbook for Michigan Fruits and Vegetables", Agric. Experiment Station, Michigan State Univ., Bulletin #418, D c., 1957

PECOT, R. K.; and WATT, B. K., "Food Yields-Summarized by Different Stages of Preparation", USDA, Agric. Handbook #102, June, 1956

Produce Packaging Association, "Bibliography-Papers on Packaging Fresh Fruits and Vegetables-1961", 1961

PUBOLS, B. H., "A Quarter Century of Peaches", USDA, The Fruit Situation, TES-139, June, 1961

PUBOLS, B. H., "A Half Century of Fruit Consumption", USDA, The Fruit Situation, TFS-140, Aug., 1961

ROCK, R. C.; and RIZZI, A. D., "The Where and When of California Fruit and Nut Crops", Calif. Agricultural Experiment Sta., Extension Service Manual 20 Dec., 1955

RYALL, A. L.; and HARVEY, J. M., "The Cold Storage of Vinifera Table Grapes", USDA, Agriculture Handbook #159, June, 1959

SCHOMER, H. A., "Reducing Mechanical Damage in Handling Apples", USDA, Biological Sciences Branch, AMS-38253, pp. 60-65

SEELIG, R. A., "Fresh Facts about the Fresh Fruit and Vegetables Industry", United Fresh Fruit and Vegetables Association, 3rd Edition, June, 1957

SELTZER, R. E., "Desert Grapefruit Goes to Market", U. of Arizona, Agricultural Experiment Station, July, 1950

SMITH, E. H. G.; and KAY, D. E., "The Utilization of Citrus Fruit", Jl. of Sc. Food and Agric., 11, April, 1960

SPANGLER, R. L.; and IDE, L. E., "Preparation of Fresh Tomatoes for Market", USDA, Farmers' Bulletin #1291, 1955

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Fresh Fruit and Vegetable Market News", AMS, Fruit & Vegetable Div., WS-40-61, Oct., 1961

U. S. DEPT. OF AGRICULTURE, ECONOMIC RES., SERVICE, "Supplement for 1960 to Comsumption of Food in the U. S. 1909-52", Agric. Handbook, No. 62, Aug., 1961

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "The Vegetable Situation", AMS, TVS-139, Jan., 1961

U. S. DEPT. OF AGRICULTURE, "Agricultural Statistics-1960", U. S. Gov., Printing Office, Washington 25, D. C. , 1961

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Bibliography-Papers on Packaging Fresh Fruits and Vegetables", AMS, Transportation & Facilities Res., Div., 1961

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE. "The National Food Situation", AMS, NFS-94, Nov., 1960

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Supplement for 1959 to Measuring the Supply and Utilization of Farm Commodities", AMS, Agric. Handbook #91, Sept., 1960

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Food Consumption and Dietary Levels of Households as Related to the Age of the Homemaker United States--by Region", AMS, Agric. Res., Service, Rpt. #14, Oct., 1959

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Farm-Retail Spreads for Food Products Costs, Prices...", AMS, Miscellaneous Publ. #741, Nov., 1957

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Supplement for 1956 to Consumption of Food in the U. S. 1909-52", AMS, Agriculture Handbook #62, Sept., 1957.

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Measuring the Supply and Utilization of Farm Commodities", AMS, Agric. Handbook #91, Nov., 1955

U. S. DEPT. OF AGRICULTURE, "The Commercial Storage of Fruits, Vegetables & Florist & Nursery Stocks", Agric. Handbook #66, Sept., 1954

WATT, B. K.; MERRILL, A. L.; ORR, M. L.; and WU, W. T., "Composition of Foods--Raw, Processed, Prepared", U. S. Dept., of Agric., Agric. Handbook #8, June, 1950

FOOD TECHNOLOGY OF NON-IRRADIATED FRESH FRUITS AND VEGETABLES

AMBROSE, A. M.; BOOTH, A. N.; DE EDS, F. ; and COX, A. J., "A Toxicological Study of Biphenyl, A Citrus Fungistat", Microbiology of Food, 25, 3, May-June, 1960

BIALE, J. B.; and YOUNG, R. E., "Critical Oxygen Concentrations for the Respiration of Lemons", Amer. Jl. of Botany, 34, 6, June, 1947

BIALE, J. B., "The Physiological Requirements of Citrus Fruits", Citrus Leaves, July, 1954

CHARLEY, V. L. S., "The Prevention of Microbiological Spoilage in Fresh Fruit", Jl. Sc. of Food and Agric., July, 1959

DEMOISE, C. F.; and MILLER, E. V., "Effect of Low Temperatures on the Physiology of Grapefruit (Citrus Paradisi MacFad.)", Notes and Letters, 24, 3, May-June, 1959

DESROSIER, N. W., "The Refrigerated Storage of Perishable Commodities", The Tech. of Food Preservation, AVI Publ. Co., Inc., 1959

DURAN, R.; and NORMAN, S. M., "Differential Sensitivity to Biphenyl Among Strains of Penicillium Digitatum Sacc"., Plant Disease Reporter, 45, 6, June, 1961

HALLER, M. H.; HARDING, P. L.; and LUTZ, J. M., "Respiration of Citrus Fruits After Harvest",

HALLER, M. H.; HARDING, P. L.; LUTZ, J. M.; and ROSE, D. H., "The Respiration of Some Fruits in Relation to Temperature, American Soc. for Hort. Sc., 1931

HARVEY, J. M.; and PENTZER, W. T., "Market Diseases of Grapes and Other Small Fruits", USDA, Agric. Handbook #189, Nov., 1960

HEINEN, J. M.; FOLINAZZO, J. F.; NANK, W. K.; and SCHMIDT, C. F., "Comparative Resistance of Strains of Clostridium Botulinum to Ionizing Radiation", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #1, Sept., 1958

JENSEN, B. C., "Studies to Determine Optimum Characteristics of In-Package Active Carbons for Removal of Irradiated Flavor During Storage", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #1, Aug., 1958

KLIS, J. B.; WITTER, L. D.; and ORDAL, Z. J., "The Effect of Several Antifungal Antibiotics on the Growth of Common Food Spoilage Fungi", Food Tech., 13, 2, Feb., 1959

MILLER, E. V., and GLASS, C. S., "Observations on the Regreening of Late Varieties of Oranges", Notes and Letters, 22, 6, Nov-Dec., 1957

ORR, M. L.; and WATT, B. K., "Amino Acid Content of Foods", USDA, Home Economics Res. Rpt. #4, Dec., 1957

PENTZER, W. T., "Storage of Agricultural Raw Products", Handbook of Food and Agriculture, Reinhold Publishing Corp., 1955

REEVE, R. M.; and NEUFELD, C. H. H., "Observations on the Histology and Texture of Elberta Peaches from Trees of High and Low Levels of Nitrogen Nutrition", Food Research, 24, 5, Sept.-Oct., 1959

SCHROEDER, W. T.; and PROVVIDENTI, R., "Tomato Fruit Disorders", Farm Research, June, 1961

SCOTT, L. E.; and TEWFIK, S., "Atmospheric Conditions--In Consumer Packages of Vegetables", Pre-Pack-Age, Sept. 1947

STEVENS, R. B., "The Fungi are Living Organisms", USDA, Yearbook of Agriculture-1953, Plant Diseases

VAS, K.; KUTZ, N.; LANG, A.; and ORBANI, T., "Factors Involved in the Interpretation of Mold Counts of Tomato Products", Food Tech., 13, 6, June, 1959

WINSTON, J. R.; HRUSCHKA, H.; and CUBBEDGE, R., "Effect of Packinghouse Treatments, Temperatures in Transit & Containers on Decay in Tangerines", U. S. Dept. Agriculture, Agric. Mktg. Service, #125, March, 1958

WOODMANSEE, C. W.; MCCLENDON, J. H.; and SOMERS, G. F., "Chemical Changes Associated with the Ripening of Apples and Tomatoes", Chemistry and Biochemistry of Foods, 24, 5, Sept.-Oct., 1959

WRIGHT, T. G., "Physiological Disorders", Plant Diseases-Yearbook of Agriculture, U. S. Dept. of Agriculture, 1953

MARKETING FRESH FRUITS AND VEGETABLES

ANDERSON, D. L.; and SHAFFER, P. F., "Improved Handling of Frozen Foods in Retail Stores", USDA, Marketing Research Rpt. #104, Sept., 1955

Anon., "The Storage of Fresh Fruits", Packaging Abstracts, 18, 9, Sept., 1961

BARGER, W. R.; HARVEY, J. M.; and RINGEL, S. M., "Shipping Mature-Green Tomatoes by Rail", Agric. Marketing, 4, 11, Nov., 1959

BARGER, W. R.; HARVEY, J. M.; and RINGEL, S. M., "Transit Temperatures of California Mature-Green Tomatoes Shipped by Rail", USDA, Marketing Research Rpt. #349, July, 1959

BRATLEY, C. O., "Refrigeration of Pre-Packaged Fruits and Vegetables", Refrigerating Engin., Dec., 1946

BREAKIRON, P. L.; and HOECKER, R. W., "A Comparative Study of Packing, Transportation & Refrigeration Costs of Bushel Baskets & Wire-Bound Boxes for Transportation of Peaches", USDA, Marketing & Facilities Research Branch, Feb., 1950

BROOKER, M. A.; and GILBRAITH, K. M., "Factors Influencing the Method of Transportation Used in Marketing Fresh Florida Citrus", Univ. of Fla., Agric., Experimental Sta., Bulletin 595, Sept., 1954

BROWNE, A. E.; CROW, W. C.; LENNARTSON, R. W.; NEWEL, S. R., et al, "Marketing-The Yearbook of Agriculture 1954", USDA, 1954

GOLDBERG, A. J., "Wholesale Prices and Price Indexes - 1959", U. S. Dept. of Labor, Bureau of Labor Statistics, Bulletin #1295, June, 1961

GUILFOY, R. F.; and JOHNSON, H. D., "Suggested Methods for Checking Temperatures of Fresh and Frozen Food Shipments", USDA, Marketing Research Rpt., #150, Dec., 1956

HALLER, M. H., "Handling, Transportation, Storage, and Marketing of Peaches", USDA, Bibliographical Bulletin #21, Dec., 1952

HARDENBURG, R. E., "Basic Facts on Maintaining FRESHNESS in Produce", Pre-Pack-Age, 10, 8, May, 1957

HAVAS, N.; HENDERSON, P. L.; PARSONS, C. S.; and SCHAFFER, P., "Displaying Fruit in Various Types of Packages and in Bulk", (Costs and Effects on Quality and Sales), USDA, AMS, Aug., 1960

HENDERSON, J. M.; and LINNENBERG, C. C., "Shifts in Rail and Truck Transportation of Fresh Fruits and Vegetables", USDA, Marketing Research Rpt. 237, June, 1958

JOHNSON, H.; and BREAKIRON, P. L, "Protecting Perishable Foods During Transportation by Truck", USDA, Handbook #105, Dec., 1956

JOHNSON, H. D.; GERRITY, M. V.; and GARVER, C. E., "Transportation Tests of Fresh Meat and Packinghouse Products in Refrigerator Cars", USDA, AMS-17, March, 1955

LEWIS, W. E., "The Shelf Life of Florida Valencia Oranges in Retail Store Display Cases", U. S. Dept. of Agriculture, H.T.&S. Office Rpt. #301, Aug., 1953

LEWIS, W. E., "Maintaining Produce Quality in Retail Stores", U. S. Dept. of Agriculture, Agriculture Handbook #117, March, 1957

LEWIS, W. E., "Temperature of Produce in Retail-Store Type Display Cases", U. S. Dept. of Agriculture, AMS-69, Sept., 1955

LEWIS, W. E., "The Shelf Life of Fresh Fruits and Vegetables in Retail Store Display Cases, U. S. Dept. of Agriculture, H.T.& S. Office Rpt. #247, Oct., 1951

LEWIS, W. E., "The Shelf-Life of Lemons in Retail Store Display Cases", U. S. Dept. of Agriculture, H.T.& S. Office Report #294, April, 1953

LEWIS, W. E., "The Shelf Life of Tangerines in Retail Store Display Cases", U. S. Dept. of Agriculture, H.T. & S., Office Rpt. #278, Aug., 1952

MANCHESTER, A. C., "Orange Tree to Breakfast Table", U. S. Dept. of Agriculture, MRR #164, June, 1957

NICHOLSON, P. A., "Changes in Citrus Fruit Marketing", USDA, Annual Meeting of Texas Citrus Mutual, AMS, June, 1961

NIGHTINGALE, F. S.; and BUNTIN, J. L., "Fresh Fruit and Vegetable Unload Totals in 100 Cities", USDA, AMS-25 (1960), April, 1961

NIGHTINGALE, F. S.; and BUNTIN, J. L., "Fresh Fruit and Vegetable Unloads in Eastern Cities by Commodities, States and Months", USDA, AMS-427, July, 1961

POWELL, L. A.; and GODWIN, M. R., "Economic Relationships Involved in Retailing Citrus Products", Univ. of Florida, Agric. Experiments Sta., Bulletin 567, Aug., 1955

REDIT, W. H.; and HAMER, A. A., "Protection of Rail Shipments of Fruits and Vegetables", USDA, Agriculture Handbook #195, July, 1961

REDIT, W. H.; and HAMER, A. A., "Precooling and Shipping Louisiana Strawberries", USDA, MRR #358, 1959

ROSE, D. H.; and GORMAN, E. A., "Handling, Precooling, and Transportation of Florida Strawberries", USDA, Technical Bulletin #525, Oct., 1936

ROSE, D. H.; COOK, H. T.; and REDIT, W. H., "Harvesting, Handling, and Transportation of Citrus Fruits", USDA, Bibliographical Bulletin #13, Jan., 1951

RYGG, G. L.; and HARVEY, E. M., "Storage Behavior of Lemons from the Desert Areas of Arizona and California", USDA, MRR #310, March, 1959

SCHOMER, H. A., "Refrigeration of Prepackaged Produce", Pre-Pack-Age, Nov., 1959

SHAFFER, P.; ANDERSON, D.; and WISCHKAEMPER, P., "Packaging and Price-Marketing Produce in Retail Food Stores (A study of Improved Methods of Marketing Agricultural Products), USDA, MRR #278, Oct., 1958

SHAW, B. T., "Losses in Agriculture", USDA, ARS-20-1, June, 1954

SORENSEN, H. B., "Marketing Texas Green-Wrap Tomatoes", Texas Agricultural Experiment Station, Bulletin 861, May, 1957

SPURLOCK, A. H.; and HAMILTON, H. G., "Costs of Packing and Selling Florida Fresh Citrus Fruits, 1959-1960 Season", Florida Agric. Experiment Sta., Agric., Economics Mimeo Rpt. #61-8, Feb., 1961

STOKES, D. R., "The State of Produce Packaging Industry and a Look at Shipping Point Packaged Produce Offerings", USDA, Produce Packaging Assoc., Produce Seminar, Jan., 1961, New Orleans, La.

STOKES, D. R., "Waste & Spoilage Losses in Merchandising Fresh Fruits & Vegetables in Bulk in Self-Service Food Stores and Statistical Supplement", USDA, Bureau of Agriculture Economics, Aug., 1947

TOLLE, W. E., "Protection of Paper-Packaged Fruits and Vegetables Displayed on Ice," USDA, MRR #293, Dec., 1958

TOOTHMAN, J. S., "Survey of Distribution Practices for Prepackaged Frozen Meat, USDA, MRR #137, Sept., 1956

U. S. DEPT. OF AGRICULTURE, AGRIC. MKTG., SERVICE, "Fresh Fruit and Vegetable Market News", AMS, Fruit & Vegetable Div., WS-38-61, Sept., 1961

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Food Costs-Retail Prices, Farm Prices, and Marketing Spreads", AMS, Rpt. #856, April, 1961

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Supplement for 1956-60 to Farm-Retail Spreads for Food Products", AMS, Marketing Economic Research Div., Rpt. #741, Jan., 1961

U. S. DEPT. OF AGRICULTURE, AGRIC., MKTG., SERVICE, "Fresh Fruit and Vegetable Shipments by Commodities, States and Months, Calendar Year 1959", AMS-36, (1959), April, 1960

WRIGHT, T. R.; and SMITH, E., "Cuts, Bruises, and Spoilage", Plant Diseases-Yearbook of Agriculture, U. S. Dept. of Agriculture, 1953

RADIATION PASTEURIZATION OF FRESH FRUITS AND VEGETABLES

AEBERSOLD, P. C., et al, "Ad Hoc Panel Report to the Interdepartmental Committee on Radiation Preservation of Foods on a National Civilian Radiation Processed Foods Program", Hearings before the JCAE Cong. of the U. S., Part 1, Jan., 1960

BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; and WRIGHT, W. R., "Effects of Gamma Radiation on Brown Rot and Rhizopus Rot of Peaches and the Causal Organisms", Phytopathology, 49, June, 1959

BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; and WRIGHT, W. R., "Effects of Gamma Radiation on Some Important Potato Tuber Decays", Amer. Potato Jl. 36, 9, Sept., 1959

BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; and WRIGHT, W. R., "Factors of Influencing the Use of Gamma Radiation to Control Decay of Lemons and Oranges, Phytopathology, 49, Feb., 1959

BERAHA, L.; SMITH, M. A.; and WRIGHT, W. R., "Gamma Radiation Dose Response of Some Decay Pathogens", Phytopathology, 50, 6, June, 1960

BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; and WRIGHT, W. R., "Gamma Radiation for Possible Control of Post Harvest Diseases of Lemons, Oranges, Strawberries, Grapes, and Peaches", Phytopathology, 47, 1957

BERAHA, L.; RAMSEY, G. B.; SMITH, M. A.; WRIGHT, W. R.; and HEILIGMAN, F., "Gamma Radiation in the Control of Decay in Stawberries, Grapes and Apples, Food Tech., 15, 2, Feb., 1961

BESSE, A. L.; and THOMPSON, D. F., "Packaging for Irradiated Subsistence Items", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #5 March, 1958

BRATZLER, L. J.; RAPHAEL, H. J.; and COSTIOLOW, R. N., "Dip Coat Packaging of Irradiated Foods", U. S. Army, Quartermaster Corps, Project # 0.1. 6169, Rpt. #10, May, 1960

BRIDGES, A. E.; OLIVO, J. P.; and CHANDLER, V. L., "Relative Resistances of Microorganisms to Cathode Rays II. Yeats and Molds", Applied Microbiology, 4, 3, May, 1956

BRILLINGER, J. H.; KALBER, W. A.; and LEYDON, A. J., "Effect of Radiation on the Physical Properties and the Sealing of Cans", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., July, 1958

BRODY, A. L., "Evaluation of Shelf Life of Irradiated Food", U. S. Army, Quartermaster, Corps, Project #7-84-01-002, Final Rpt., July, 1958

BROWNELL, L. E.; and PUROHIT, S. N., "Combining Gamma Radiation, Refrigeration", Refrigerating Engin., June, 1956

BROWNELL, L. E.; KEMPE, L. L.; and GRAIKOSKI, J. T., "Gamma Rays: The Hope of Researchers to Lenghten Refrigerated Life of Fresh Foods",

BROWNELL, L. E.; NEHEMIAS, J. V.; and BULMER, J. J., "Proposed New Methods of Wholesaling Fresh Meat Based on Pasteurization by Gamma Irradiation", USAEC, AECU-3043, Project 1943-7, Contract #AT (11-1)-162, Dec., 1954

BROWNELL, L. E.; KUIPERS, K.; and EZMAN, L., "Radiopasteurization of Food", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #5, July, 1958

BROWNELL, L. E.; KUIPERS, K.; BURCHFIELD, A.; JUDGE, P., et al, "High Radiopasteurization of Foods", U. S. Army, Quartermaster Corps, Project # DA-19-129-AM-756, Final Rpt., Sept., 1957

BURNS, E. E.; and DESROSIER, N. W., "Maturation Changes in Tomato Fruits Induced by Ionizing Radiation", Food Tech., 11, 6, 1957

COLEBY, B.; HORNE, T.; INGRAM, M.; and JEFFERSON, S., "Radiation Processing of Foods in Britain", Nucleonics, Nov., 1958

COLLINS, H. E., "Design of Containers for Irradiated Foods", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., July, 1959

DENNY, C. F.; BOHRER, C. W.; PERKINS, W. E.; and TOWNSEND, C. T., "Destruction of Clostridium Botulinum by Ionizing Radiation", Food Radiation, 24, 1, Jan.-Feb., 1959

DUGGAN, D. E.; ANDERSON, A. W.; and ELLIKER, P. R., "Ultraviolet Exposure Studies on a Gamma Radiation Resistant Micrococcus Isolated From Food", Radiation Preservation of Food, 24, 4, July-Aug., 1959

EMERY, D. F.; and ANDREWS, J. S., "Food Irradiation", G neral Mills Research Bulletin, Progress thru Research, 1956

EUKEL, W. W.; and HUBER, W., "Tooling Up for Low Dose Irradiation Processing of Fresh Foods", Food Tech., 14, 4, April, 1960

FAGERSON, I. S., "Effect of Irradiation on Pigmented Foods Used in Rations for the Armed Forces", U. S. Army, Quartermaster Corps, Project #7-84-01-002 Final Rpt., May, 1956

FEAZEL, C. E.; BURKS, R. E.; MOSES, B.; and TRIPP, G. E., "Testing Packages for Irradiated Foods", Packaging Engin., 5, 4, April, 1960

FEAZEL, C. E. "Determination of Effect of Packaging Materials on the Properties of Irradiated Foods", U. S. Army, Quartermaster Corps., Project #-7-84-01-002, Final Rpt., March, 1958

FEAZEL, C. E.; MOSES, B. C.; BURKS, R. E., et al, "A Study of Irradiation in Combination with M del Food Systems on the Functional Properties of Food Containers", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #10, March, 1958

FIELDS, M. L.; AMMERMAN, G. R.; and DESROSIER, N. W., "A Study of the Growth of Aspergillus Oryzae In Irradiated Components of Foods", Food Tech., Aug., 1960

FRANCIS, F. J., "Determination of Pigment Changes Occurring In Irradiated Plant Products During Post-Irradiation Storage", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., Sept., 1957

GERNON, G. D., "Ray-Pasteurizing of Produce Will Come First, Food Engin., May, 1959

GLASS, R. A.; and SMITH, H. D., "Radioactivities Produced in Foods by High-Energy Electrons," U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #10, Dec., 1959

GRONBECH, G., "Consumption Trends and Patterns for Vegetables, Potatoes, Sweetpotatoes, and Dry Beans and Peas", USDA, Agric. Handbook, #215, July, 1961

HANNAN, R. S., "The Preservation of Foods With Ionizing Radiations", Food Sc. Abstracts, 26, 2, 1954

HANNAN, R. S., "Research on the Science and Technology of Food Preservation by Ionizing Radiations", Chemical Publ. Co., Inc., 1956

HANNAN, R. S., "Low Temperature Research Station Radiation Group", L.T.R.S. Record Memorandum 314, Oct., 1955 - Dec., 1957

KEMPE, L. L.; GRAIKOSKI, J. T.; and BROWNELL, L. E., "Ray-Sterilizing Food Wrappers", Food Engin., Nov., 1953

KERTESZ, Z. I., "A Study of the Radiation-Induced Softening of Plant Tissues", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Jan., 1959

KRAYBILL, H. F., "Current Status of Applications in the Pasteurization or Sterilization of Foods by Ionizing Radiations", 2nd Annual Texas Conf. on Utilization of Atomic Energy, E-72-60 Nov., 1959

LARSON, W. S., "Investigation of Containers for Radiation Preservation of Food", U. S. Army Quartermaster Corps, Project #7-84-01-002, Final Rpt Dec., 1959

LAUGHLIN, H. F., "Studies to Determine Optimum Characteristics of In-Package Active Carbons for Removal of "Irradiation Flavor" During Storage", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #3, Dec., 1958

MARKAKIS, P.; LIVINGSTON, G. E.; and FAGERSON, I. S., "Effects of Cathode Ray and Gamma Ray Irradiation on the Anthocyanin Pigments of Strawberries", Radiation Preservation of Food, 24, 5, Sept.-Oct., 1959

MARTIN, D. C., "The Extension of Storage Life of Fresh Fruits and Vegetables by Ionizing Radiation", U. S. Army, Quartermaster Corps, Project #-7-84-01-002, Rpt. #2, Oct., 1955

MEHRLICH, F. P.; and LITTLEJOHN, J. P., "Radiation Preservation of Foods Project", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #14-16, June, 1961

MORGAN, B. H., "Radiation Chemistry of Foods - 1958", CCC Research & Development, 1958

MORGAN, B. H., "Current Status of Radiation Preservation of Foods: Part II", Food Processing, July, 1957

MORGAN, B. H.; and SIU, R. G.H., "Action of Ionizing Radiations on Individual Foods", Radiation Preservation of Food, U. S. Army, Quartermaster Corps., Aug., 1957

MCARDLE, F. J.; and NEHEMIAS, J. V., "Effect of Y-Radiation on the Petic Constituents of Fruits and Vegetables", Food Tech., 10, 12, 1956

MCBRIAN, R., 'Use of Ionizing Radiations to Preserve Fruits and Vegetables, U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #1, Feb., 1960

MCBRIAN, R., "Use of Ionizing Radiations to Preserve Fruits and Vegetables", U. S. Army, Quartermaster Corps., Project #7-84-01-002, Rpt. #5, Aug., 1959

NELSON, K. E.; MAXIE, E. C.; and EUKEL, W., "Some Studies in the Use of Ionizing Radiation to Control Botrytis Rot in Table Grapes and Strawberries", Phytopathology, 49, Aug., 1959

O'BRIEN, R., "Investigation of the Effects of Irradiation on Foods Packaged in Hermetically Sealed Aluminum Foil Containers", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #1, Aug., 1958

PHILLIPS, A. W., "The Chemical Enhancement of Bacterial Radio-Sensitivity in the Radiation Sterilization of Foods", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., Dec., 1959

PRATT, G. B.; and WILBUR, A. C., "Corrosion Studies of Irradiated Canned Foods", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Annual Rpt. #5, Sept., 1960

PRATT, G. B.; WHEATON, E.; BOHRER, C. W.; and DENNY, C. B., "Destruction of Clostridium Botulinum by Ionizing Radiation Part II., Peas, Chicken, Soup, and Port in the Frozen State", Food Radiation, 24, 1, Jan.-Feb., 1959

PRATT, G. B., "Research Study on Can Enamels as Part of the Radiation Preservation of Foods Program", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., May, 1960

PROCTOR, B. E.; NICKERSON, J. T.R.; LICCIARDELLO, J. J.; GOLDBLITH, S. A.; and LOCKHART, E. E."Extension of Food Storage Life by Irradiation", MIT, Dept. of Food Tech., June, 1955

ROMANI, R. J.; MAXIE, E. C.; and ROBINSON, B. J."Radiation Preservation of Fresh Strawberries and Grapes", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., March, 1961

SALUNKHE, D. K., "Gamma Radiation Effects on Fruits and Vegetables", Economic Botany, #15, 1961

SALUNKHE, D. K.; POLLARD, L. H.; BERBER, R. K.; WILCOX, E. B.; and SIMON, M.,"Packaging Effects on the Flavor and Shelf Life of Gamma-Irradiated Fresh Fruits and Vegetables", Package Engineering 4:2 (1959)

SALUNKHE, D. K., "Studies on Radiation Preservation of Fruit and Vegetables Products", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., Nov., 1959

SCHMIDT, D. F.; and NANK, W. K., "Radiation Sterilization of Food I. Procedures for the Evaluation of the Rad. Resistance of Spores of Clostridium Botulinum in Food Products", Food Research, 25, 3, May-June, 1960

SCHULTZ, H. W.; CAIN, R. F.; BUBL, E. C.; and NORDAN, H. C., "Effect of Ionizing Radiation on Acceptance of Foods", Supt. of Documents, U. S. Printing Office, Washington 25, D. C., TID-7512, Conf. on Radioactive Isotopes in Agric., Jan., 1956

SKIBBE, A. G.; and PETERSON, G. T., The Determination of the Suitability of Aluminum Containers for the Packaging of Irradiated Foods", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #5, Feb., 1961

SMITH, M. A.; and BERAHA, L., "Control of Post Harvest Diseases of Fruits and Vegetables by Radiation Treatments", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #5, May, 1958

Stanford Research Institute, "Radiation Preservation of Selected Fruits and Vegetables", USDEC, SRIA-30, Contract #AT(04-3)-115, Project Agreement #23, TID-4500 (16th Edition) Jan., 1961

TAIMUTY, S. I.; DELARUE, R. E.; OKADO, A.; and VELDEE, M. V., "A Comparative Study of the Effects of High and Low Intensity Radiations in Food Sterilization", U. S. Army, Quartermaster Corps, Project #7-84-01-002, Rpt. #9, Aug., 1957

THOMPSON, B., "Post-Harvest Treatments of Strawberries and Radishes with Cobalt-60 Irradiation", Proceedings of the Fla. State Hort. Soc., 72, Oct., 1959

TRIPP, G., "Fresh Fruits & Vegetables", QMC, Inter. Jl. of Appl. Radiation & Isotopes, 6, Oct., 1959

TRIPP, G., "Packaging for Irradiated Foods", Radiation Preservation of Food by the U. S. Army, Quartermaster Corps, #1, Aug., 1957

TRIPP, G. E., "Packaging for Irradiated Foods", Presented before Packaging Institute, Hotel Statler, Cleveland, Ohio, Sept., 1956

TRIPP, G. E., "Packaging for Irradiated Foods", International Jl. of Applied Radiation & Isotopes, 6, 1959

TRUELSEN, T. A., "Irradiation of Fresh Fruits and Vegetables with Pasteurizing Doses", 1st Nordic Meeting on Food Preservation by Ionizing Radiations" Riso Rpt. #16, July, 1960

U. S. ARMY, QMF&CI., "Radiation Preservation of Foods Project ", QMF&CI, Rpt. #4-59, March, 1959

U. S. ATOMIC ENERGY COMMISSION, "Food Irradiation and Associated Studies-Termination Rpt. Part I", NYO-3320, Sept., 1954

URBAIN, W. M., "Progress and Problems in Radiation Processing of Food", Jl. of Agric. and Food Chemistry, 8, 5, Sept.-Oct., 1960

VILLARREAL, F.; LUH, B. S.; and ROMANI, R. J., "High-Velocity Electron Irradiation of Tomato Paste", Food Tech., 15, 4, 1961

WAGENAAR, R. O.; DACK, G. M.; and MURRELL, C. B., "Studies on Purified Type a Clostridium Botulinum Toxin Subject to Ultracentrifugation and Irradiation", Food Research, 24, 1, Jan-Feb., 1959

WHEATON, E.; PRATT, G. B., and JACKSON, J. M., "Radioresistance of Five Strains of Clostridium Botulinum in Selected Food Products", Jl. of Food Sc. 26, 4, July-Aug., 1961

RELATED INFORMATION ON FRESH FRUITS AND VEGETABLES

Anon., "The Use of Ionizing Radiations for Food Preservation", Food & Agric. Organization Conf., Nov., 1958, Chemistry & Industry, Feb., 1959

BITTING, H.W., "New Developments in the Frozen Food Industry ...", USDA, Marketing Research Rpt. #236, May, 1958

BOGARDUS, R.E., "Wholesale Fruit and Vegetable Warehouses - Guides for Layout and Design", USDA, Marketing Research Rpt. #467, Aug., 1961

BOWMAN, R.E., "How Radiation Affects Engineering Materials", Materials in Design Engin., Manual #173, July, 1960

BRODY, A.L., "Present Status of Radiation Preservation", Atomic Industrial Forum, Conf., Paper #57 - AIF-12, Oct., 1957

BROWNELL, L.E.; NEHEMIAS, J.V.; and BULMER, J.J., "The Design of a Gamma Irradiation Facility for the Control of Insect Infestation in Flour, Meal, or Grain", USAEC, AECU-3050, Project #1943-7, Contract #AT (11-1) - 162, May, 1955

BRUNELET, L.; and VIDAL, P., "Some Aspects of the Problem of Packaging Food Products Which Have Been Sterilized by Ionizing Radiation", USAEC, AEC-tr-3691, June, 1959

Can Manufacturers Institute, Inc., "Test Procedures for Determining the Approximate Amount of Extractables from Coated Food and Beverage Containers and Closures," Aug., 1960

CHARM, S.E.; GOLDBLITH, S.A.; and PROCTOR, B.E., "Theoretical Considerations in Food Processing by Gamma Radiations - II A Simplified Mathematical Procedure for Evaluating Gamma Radiation Processes Inside Hallow Cylinder Sources", Food Tech., 12, 5, May, 1958

CHRISTENSEN, C.J.; JACOBSEN, A.T.; KLINGER, Q.; and EVANS, M.D., "Dugway Cobalt- 60 Irradiation Facility", Tech. Report, DA-18-108-CML-5347, Jan., 1959

CLAYPOOL, L.L.; and DAVIS, L.D., " The Effect of Cold and Modified Atmosphere Storage on the Canning Quality of Cling Peaches", Food Tech., 13, 3, March, 1959

COLLINS, H.E., "Design of Containers for Irradiated Foods", U.S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, July, 1959

DESROSIER, N.W.; and ROSENSTOCK, H.M., "Radiation Effects on Packaging Materials", Radiation Tech. in Food, Agri. and Biology, AVI Publ. Co., Inc., 1960

DESROSIER, N.W., "Preservation of Food with Ionizing Radiations", The Tech. of Food Preservation, AVI Publ. Co., Inc., 1959

DUNCAN, D.T.,; HOOKER, W.J.; and HEILIGMAN, F., "Storage Rot Susceptibility of Potato Tubers Exposed to Minimum Sprout Inhibiting Levels of Ionizing Radiation", Food Tech., 13, 3, March, 1959

FARRALL, W.A., "Five Year's Use of the 1,000,000 Volt Electron Beam Machine", Michigan State University, Sept., 1961

GOLDBLITH, S.A.; and PROCTOR, B.E., "Evaluation of Food Sterilization Efficiency", Nucleonics, 10, 9, Sept., 1952

GUADAGNI, D.G.; DOWNES, N.J.; SANSHUCK, D.W.; and SHINODA, S., "Effect of Temperature on Stability of Commercially Frozen Bulk Pack Fruits-Strawberries, Raspberries, and Blackberries", Food Tech., 15, 4, April, 1961

HARDENBURG, R.E., "Polyethylene Box Liners for Storage of Golden Delicious Apples", USDA, Marketing Research Rpt. #461, March, 1961

HEINEN, J.M.; DAVIS, R.B.; and DOWLING, J.E., "Radiation Sterilization of Canned Foods", U.S. Army, Quartermaster Corps, Project #7-84-01-002, Final Rpt., Oct., 1956

HUBER, W.; and KLEIN, A.S., "Cuts Food Radiation Costs", Food Engin., Jan., 1960

KRAYBILL, H.F.; and BRUNTON, D.C., "Commercialization Technology and Economics in Radiation Processing", Agric. and Food Chemistry, 8, 5, Sept.-Oct., 1960

MEHRLICH, F.P., "The Current Outlook for Radiation Processed Foods", Activities Rpt., 13, March, 1961

MEHRLICH, F.P., "Progress is Being Made in Food Radiation", Food Processing, 22, 5, May, 1961

MULLINS, W.R.; and BURR, H.K., "Treatment of Onions with Gamma Rays: Effects of Delay Between Harvest and Irradiation", Food Tech., 15, 4, 1961

NICHOLAS, R.C.; and WIANT, D.E., "Radiation of Important Grain-Infesting Pests: Orders of Death Curves, and Survival Values for the Various Metamorphi Forms", Food Tech., 13, 1, Jan., 1959

PAWSKI, L.; and FINDLEN, H., "Handling and Shipping Potatoes to Processing Plants in Pallet Boxes and Burlap Bags", USDA, MRR No. 459, Sept., 1961

PROCTOR, B.E., "Development of a Method of Radiation Sterilization of Foods Without Adverse Flavor and Chemical Changes", U.S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, April, 1957

PROCTOR, B.E., "Procurement of Services Pertinent to the Determination of Bacterial Resistance of Packages", U.S. Army, Quartermaster Corps, Project #7-84-01-002, Final Report, March, 1958

READ, M.S., "Current Aspects of the Wholesomesness of Irradiated Food", Engineers Joint Council, Nuclear Engineering & Science Conference, New York, April, 1960

REESE, R.B., "Production of Frozen Prepared Foods- 1954-1955", USDA, Rpt. #170, May, 1957

SAINSBURY, G.F.; and SCHOMER, H.A., "Influence of Carton Stacking Patterns on Pear Cooling Rates", USDA, MRR #171, April, 1957

Stanford Research Institute, "Insuring the Safety of Irradiated Foods", Research for Industry, 13, 1, Jan. - Feb., 1951

STOKES, D.R., "Pear Packaging 1960-61", USDA, Oregon-Washington-California Pear Bureau Conf., May, 1961

STOLLSTEIMER, J.F.; and SAMMETT, L.L., "Packing Fresh Pears", California Agriculture, Oct., 1961

TRAYLOR, H.D., "Some Effects of Use of Polyethylene Bags and Uniform Sizing on Retail Potato Sales," Cornell University, A.E. Res. 13, Feb., 1959

TRESSLER, D.K.; and EVERS, C.F., "The Freezing Preservation of Foods-Volume I- Freezing of Fresh Foods", The AVI Publishing Co., Inc., 1957

U.S. ARMY, QMF & CI, " Experimental Determination of Dose Distribution in a No. 10 Can", QMF & CI, Rpt. #32-57, Aug., 1957

U.S. ARMY, QMF & CI, "Food Preservation by Irradiation", QMF & CI Activities Rpt. #9, Jan. 1957

U.S. ARMY, QMF & CI, "Precooked Frozen Foods", QMF & CI, Simposium, Chicago, Illinois Dec., 1955

U.S. ARMY, OFFICE OF THE QM GENERAL, "Establishing Optimum Conditions for Storage and Handling of Semiperishable Subsistence Items", Conference, Research & Development Div., QM Corps, March, 1955

U.S. ARMY, QMF & CI, "Low Temperature Test Methods and Standards for Containers", QMF & CI, Symposium, Chicago, Illinois, Sept., 1954

U. S. DEPT. OF COMMERCE, "U. S. Army Panel Discussion on Radiation Preservation of Food", OTS-PB 121103, April, 1956

URBAIN, W. M., " Progress and Problems in Radiation Processing of Food", J. of Agricultural and Food Chemistry, 8, 5, Sept. -Oct., 1960

WHITNEY, W. K.; NELSON, S. O.; and WALKDEN, H. H., "Effects of High-Frequency Electric Fields on Certain Species of Stored-Grain Insects", U. S. Dept. Agriculture, Agric. Mktg. Service, Marketing Research Rpt. #455, March, 1961

GLOSSARY

Glossary of Terms and Abbreviations

A	Abbreviation for angstrom, a unit of length often employed in specifying wavelength. An angstrom is equal to 10^{-10} meter.
AEC	Atomic Energy Commission
alpha particle	One of the particles emitted from the atomic nuclei of radioactive substances during their spontaneous disintegration. It is the same as the nucleus of the predominate helium isotope and consists of two protons and two neutrons. Being strongly absorbed by air, alpha particles are not used for food irradiation.
anaerobic bacteria	A class of bacteria which grow only in the absence of free oxygen.
anti-rad	An added substance which reduces the effect of radiation upon organic material.
autolysis	The process of self-digestion in plant and animal tissues, especially, after separation from the parent organism to which they belong, as in fruit after picking or in seafood after death.
beta particle	One of the particles emitted from the atomic nuclei of some radioactive substances during their spontaneous disintegration. It is the same as an electron.
blister	A small, localized, un-adhered and raised area between two mating surfaces which otherwise are tightly bonded together.
board	Paper or other fibrous substance generally 6 mils or thicker. See also boxboard and paperboard.
bond strength	Also known as peel seal strength. A measure of the force required to separate two bonded faces, the pull being applied in a straight line at a specified rate such as 12 in. /min. There are numerous units of bond strength such as grams/inch of width and pounds/inch of width.

boxboard	Paper or other fibrous substance of sufficient thickness and strength so that it can be used in the manufacture of boxes.
brightness	The directional reflectance of blue light (wavelength about 4600 angstroms) as measured under standard conditions on a reflectometer. See ASTM Method D-985-50.
bursting strength	The pressure, often expressed in pounds per square inch, required to rupture a sample of paper, flexible plastic sheet, etc., under specified test conditions. It is largely determined by the tensile strength and extensibility of the specimen. The bursting strength is an important measure of the strength of packaging materials.
CCC	Continental Can Company, Inc.
CD	Cross direction. See CMD.
C-enamel	An oleoresinous enamel containing zinc oxide employed on the inside of tin-plate cans used to package sulfur-containing food. It avoids discoloration due to dark tin and iron sulfide formation. Also called "corn enamel."
clarity	A qualitative term referring to the absence of haze in a transparent sample. See haze.
CMD	Cross machine direction; also called transverse, TD and CE. The direction at right angles to the direction of motion in the plane of a web of packaging material such as paper or plastic.
color difference	The result of measuring small differences between surface colors by means of meters such as those produced by Gardner and Hunter. These color differences correlate reasonably well with visual judgments. See ASTM Method D 1365-60T.
cross-linking	The joining of adjacent long-chain molecules to form an inter-connected network.
CTC	Chlortetracycline, an anti-biotic used to retard food spoilage.

CTFE	Chlorotrifluoroethylene. As a polymer is used in food packaging in the form of thin films or coatings.
dose	The energy per unit of mass absorbed by a substance subjected to ionizing radiation. The generally accepted unit of dose in the rad. A substance receives a dose of one rad when each gram absorbs 100 ergs. A megarad is one million rads. The rad is more frequently used than an earlier unit called the rep.
electron	A fundamental particle of matter with a rest mass of $9.11{:}10^{-31}$ kilograms and a charge of $1.60{:}10^{-19}$ coulombs. A beam of high speed electrons, produced by an accelerator, is a common form of ionizing radiation useful in pasteurizing foods.
electron accelerator	A device which produces a beam of high-speed electrons. Food may be pasteurized or sterilized with an electron accelerator of which there are several kinds, such as, resonant transformer, Van de Graaff generator, linear accelerator, etc.
elongation	The amount of strength to which a material is subjected, generally expressed as the percent increase in length of a specimen under tension.
elongation at break	The percent elongation at which a sample ruptures.
extractability	The migration of the components of a packaging material into a solvent or solution with which the packaging material is in contact, usually expressed as mg/sq in. of packaging material, ppm in the extracting solution, or percentage extractability of the packaging material.
FB	Fibreboard.
FDA	Food and Drug Administration of the United States Department of Health, Education and Welfare.
fillet	A piece of boneless flesh cut away from the side of a fish along the backbone behind the pectoral fin to the tail section.
fold endurance	The number of folds under specified test conditions required to cause a sample of flexible packaging material to fail. Also known as folding endurance.

flexural strength	The maximum stress at the moment of crack or break in the outer fiber of a specified beam of homogeneous, elastic material, tested in flexure as a simple beam supported at both ends and loaded at the midpoint. The maximum stress in the outer fiber occurs at midspan. See ASTM Method D790-59T.
flint glass	A common term for clear, colorless container glass used for jars, bottles, etc.
foil	As used in this report, foil refers to a thin sheet of aluminum or its alloys 0.0045 inch or less in thickness. The foil in laminations is frequently about 0.00035 inch thick.
gamma radiation	Electromagnetic radiation emitted from the nuclei of many radioactive atoms. Gamma radiation from cobalt-60, spent fuel elements, Cs-137 and other radioactive sources may be used to pasteurize and sterilize food products.
gas permeability	See permeability.
Gelbo test	See MVT Gelbo Flex.
glassine paper	A smooth, dense paper made from well-hydrated fibers and frequently supercalendered. It is more glossy and more resistant to grease, oil and fat than "greaseproof" paper. Generally it is transparent or semi-transparent.
greaseproof paper	Paper made from well-hydrated fibers and rendered resistant to grease, fat and oil by special papermaking processes. Also known as grease-resistant paper.
haze	"That percentage of transmitted light which, in passing through the specimen, deviates from the incident beam in forward scattering by more than 2.5° on the average. The method is not intended for use when haze is greater than 30%". See ASTM Method D-1003-49, and also A.C. Webber J. Op. Soc. Am., 47, 785 (1957).
heat seal response	Also known as heat seal rating and heat seal curve. The bond strength is determined as a function of temperature, jaw pressure and dwell time to simulate conditions on an actual closing machine. The pressure is typically 20-40 psi, the dwell time 1/4 to 1 sec and the temperature varied by 125-150°F over a range suitable to the particular system involved.

HS coated	Coated so as to be heat-sealable.
impact strength	Resistance of a material to impact, frequently measured by the use of a falling ball or a pendulum striking the sample under carefully specified conditions.
ion	An atomic particle, atom, molecular or radical bearing an electric charge, either positive or negative.
ionization	Any process which results in the formation of ions.
ionizing radiation	Any particle or electromagnetic radiation which causes ionization, including high-speed electrons, protons, gamma rays, x-rays, alpha-particles, etc.
kraft	A strong paper or board made by the sulfate process and widely used in packaging. Kraft is the German word for "strength."
liner	The term liner is used in many different contexts to designate one ply of a multi-ply material. Frequently, the liner is of superior quality and is the material in contact with the packaged product.
lipid	A class of fatlike compounds related to the fatty acid esters.
MD	Machine direction; also called longitudinal. The direction of motion of a web of packaging material such as paper or plastic.
megarad	Also written M rad. A radiation dose equal to one million rads.
Mev or MEV	Million electron volts. A unit of energy equal to that acquired by an electron when it is accelerated through a potential difference of one million volts.
MG	Mature green.
MID	Meat Inspection Division of the U. S. Department of Agriculture.
MIT	Massachusetts Institute of Technology.

MLD or LD 50 — Median lethal dose. The radiation dose required to kill 50% of the individuals in a large group of organisms or animals within a specified period of time. It is important to know the MLD of organisms injurious to food when specifying the details of a pasteurization or Sterilization process.

modulus — The ratio of the stress to the strain in elastic deformation.

MP — 1. Melting point. 2. Moisture-proof.

MVT — Moisture vapor transmission. A measure of the quality of flexible packaging materials, often rated in units of grams of water vapor diffusing through an area of 100 square inches in 24 hours at 100F for a sample one mil thick, 90% relative humidity on one side and 0% relative humidity on the other. Other values of relative humidity may be specified. Also known as WVT.

MVT Gelbo Flex — A tube of the plastic film under test is made by heat sealing two edges of a plane sheet. One end of the tube is held fixed while the other is twisted thru a specified angle for several cycles. The MVT increases with number of cycles. The Gelbo test was developed by the Air Force to simulate rough handling of bags enclosing aircraft engines. Test results may also correlate with rough handling of other products and package designs but this has not yet been fully established. See Military Barrier Specification MIL-B-131B.

MW — molecular weight.

neutron — A fundamental particle of matter having no net electric charge and a mass approximately equal to the mass of a proton $1.67 \cdot 10^{-24}$ gram. Neutrons are not used in food irradiation.

NG — Not given.

nucleus — The center of core part of an atom, consisting chiefly of protons and neutrons. The electric charge of a nucleus is always positive. Plural: nuclei.

organoleptic — Pertaining to the senses, particularly those of smell and taste.

paperboard	Board of paper or other fibrous material generally at least 12 mils thick. See also board and boxboard.
parchment	Originally a sheet of animal skin suitable for writing. Now the term vegetable parchment is used either for a grease-resistant sulfite paper used for greeting cards or for a paper specially treated to resist water, salt solutions, etc., as well as grease, fats and oils. Certain forms of parchment are widely used for wrapping butter, cooking vegetables, etc.
pasteurization radiation	As used in this report, pasteurization is a shelf-life extension radiation process in which the total dose is one megarad or less. This process checks or delays microbial decomposition of food and other substances. Pasteurization destroys some of the contained micro-organisms.
PE	Polyethylene.
peel seal	An easy-opening package incorporating a non-fused seal. Each component of the seal is relatively clean after separation.
peel strength	See bond strength.
penetration	The rate at which ink, water, etc., penetrates into a sheet of board, paper, plastic, etc., as determined by various standardized tests.
permeability	A measure of the rate of transport of a fluid, such as water or oxygen, through a film of flexible packaging material. A unit often used for gas permeability is ml per 100 square inches per 24 hours for a pressure gradient of one atmosphere across a sample one mil thick, at a specified temperature.
pin blister	A very small blister.
psychrophilic bacteria	A class of bacteria which thrive at low temperatures, principally below 20C.
pulp	A mixture of cellulose-type fibers, fillers, etc., ground and suspended in water. The word pulp is also used for a dry, in-process material of similar composition.

QMC	The Quartermaster Corps of the United States Army.
rad	A unit of radiation dose equal to the absorption of 100 ergs by each gram of the substance. A megarad is one million rads. See dose.
radiation	As used in this report, radiation is a stream of x-rays, gamma rays, electrons or beta rays which, falling on food in a controlled process, enhances its keeping quality.
rep	Roentgen-equivalent-physical. See dose and rad.
resin	A class of natural or synthetic polymer.
RHC	Rubber hydrochloride.
SC	Sealing compound.
seal strength	A measure of the strength of the seal between two plastic surfaces, frequently expressed in units of grams per inch of width required to separate them.
size	Resin, alum, starch and similar materials added to pulp or applied to the surface of paper and board in order to provide special functional characteristics, such as water-repellancy, printability, grease resistance, etc.
spent fuel elements	Fissionable material removed from an atomic reactor after reaching the end of its economic life. While no longer suitable for reactor use, a spent fuel element may still be employed as a source of radiation for food irradiation. The average energy of the radiation is about 0. 8 Mev.
sterilization, radiation	Sterilization means the freeing of any object or substance from all life of any kind. There is no distinction as to the kinds of microorganisms destroyed, whether pathogenic or non-pathogenic, whether vegetative or spore forms. Sterilization by radiation usually requires a dose between 3 and 6 megarad.
stiffness	Resistance to bending. The stiffness of a sample depends upon its dimensions and the Young's modulus of the material of which the sample is made. In describing paper stiffness may be defined to depend also upon the basis weight (weight per unit area).

stress-flex test	A durability test for cellophane in which rubber clamps on the long edges of a 4" x 7" sample are oscillated in opposite directions parallel to the long edges at a rate of 76 times per minute. The number of strokes to failure is indicated on a counter. See reference 338.
sulfate paper	Paper prepared by cooking wood in a solution of sodium hydroxide and sodium sulfide. The cook is generally less severe than in the sulfite process and it produces a stronger pulp. See kraft.
sulfite paper	Paper prepared by cooking wood under pressure in a solution of calcium, magnesium or other acid sulfites. Sulfite papers are used for writing, books and some high-quality containers.
TAPPI	Technical Association of the Pulp and Paper Industry.
TD	Transverse direction; also called CMD and CD.
tear strength	The resistance of a material to tearing as measured under specified conditions such as in an Elmendorf tear tester.
tensile strength	The maximum stress which a sample can sustain under tension without failing, often stated in units of pounds per square inch or dynes per square centimeter.
thermoplastic	A thermoplastic polymer softens on heating. Examples are polyethylene, nylon and cellulose acetate.
thermosetting	A thermosetting material reacts on heating to form an insoluble, infusible polymer. Examples are phenolics, styrene and urea-formaldehyde.
TMA	Trimethyl amine.
TMN	Trimethyl amine nitrogen. The TMA content reported in terms of the nitrogen present.
transparency ratio	Same as transmittance. The fraction of light transmitted by a plane sample in a direction prependicular to the surface.
USDA	United States Department of Agriculture.
USDI	United States Department of the Interior.

Van de Graaff generator	An electrostatic generator that employs a moving, nonconducting belt to carry electrical charges to the interior of a hollow conductor, such as a hollow sphere. There the charges are surrendered to the conductor. A Van de Graaff generator may delivery up to 3 million volts.
WVT	Water vapor transmission. See MVT.
X-rays	Electromagnetic radiation of wavelength roughly between 0.1 and 100 angstroms produced when high speed electrons strike any material. X-rays easily penetrate most substances. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays and to those of short wavelength originating in the extranuclear part of the atom as x-rays.

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